The Current and Projected Future Market for Battery Chargers and External Power Supplies

U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
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LIST OF ACRONYMS

AC	alternating current
AHAM	Association of Home Appliance Manufacturers
BC	battery charger
C	battery capacity in ampere-hours
CEA	Consumer Electronics Association
CFR	Code of Federal Regulations
CSA	Canadian Standards Association
DC	direct current
DOE	U.S. Department of Energy
DVD	digital video disk
EIA	Energy Information Administration
EPA	U.S. Environmental Protection Agency
EPACT 2005	Energy Policy Act of 2005
EPCA	Energy Policy and Conservation Act of 1975
EPS	external power supply/supply
EPSMA	European Power Supply Manufacturers Association
EU	European Union
FR	Federal Register
GPS	global positioning system
Hz	hertz (cycles per second)
kG	kilogauss
kHz	kilohertz (1,000 cycles per second)
kWh	kilowatt-hours
LBNL	Lawrence Berkeley National Laboratory
LCD	liquid crystal display
Li-Ion	lithium ion
mW	milliwatts
MW	megawatts
NiCd	nickel cadmium
NOPR	notice of proposed rulemaking
NRCan	Natural Resources Canada
OEM	original equipment manufacturer
PDA	personal digital assistant
PSMA	Power Sources Manufacturers Association
PTI	Power Tool Institute
PWM	pulse width modulated
RMS	root mean square
TV	television
UL	Underwriters Laboratories
USB	universal serial bus
U.S.C.	United States Code
V	volts
W	watt
W/lb	watts per pound

1. INTRODUCTION

This report, *The Current and Future Market for Battery Chargers and External Power Supplies* is associated with DOE's work preparing for the scoping workshop and determining whether to consider energy conservation standards for these products. This document is published in conjunction with a second report, *Plans for Developing Energy Conservation Standards for Battery Chargers and External Power Supplies*.[1] Together, these two documents represent the Framework Document for these products and present the Department's initial understanding of the market for these products, the steps it will follow in conducting a determination analysis to determine if standards should be considered for battery chargers (BCs) and/or external power supplies (EPSs), and its plans for developing energy conservation standards, should there be a positive determination.

Section 325(u) of the Energy Policy and Conservation Act (42 U.S.C. 6291 *et seq*.; EPCA), as amended by the Energy Policy Act of 2005 (Pub. L. 109-58; EPACT 2005), directs DOE to "assess the current and projected future market for BC and EPS" in establishing test procedures for these products (42 U.S.C. 6295(u)(1)(B)(ii)). EPCA directs DOE to include, within this assessment, estimates of the significance of potential energy savings from technical improvements to these products and to suggest product classes for energy conservation standards (42 U.S.C. 6295(u)(1)(C)). Consistent with these statutory directives, this document presents information that will be used throughout the determination analysis.

This document is divided into three sections: (1) the market assessment, (2) the technology assessment, and (3) scope of coverage and product classes. In the market assessment, DOE qualitatively and quantitatively characterizes the structure of the markets for

BCs and EPSs. It identifies key market actors, maps distribution channels, estimates market shares and trends, and addresses regulatory and non-regulatory initiatives likely to impact the efficiency of BCs and EPSs. The market assessment concludes with a brief discussion of energy savings potential. In the technology assessment, DOE characterizes the functional designs of BCs and EPSs, describes how these devices use energy, and identifies opportunities to reduce energy consumption. In the scope of coverage and product classes section, DOE solicits stakeholder comment on defining the scope of coverage for the determination. DOE also solicits comment on methods of classifying BCs and EPSs, including whether some products might warrant being classified as both a BC and an EPS.

Issue Boxes: *While DOE invites comments from stakeholders on all aspects of the material presented in this document, there are several issues in particular on which DOE seeks comment and that are identified in boxes such as this one. These boxes are numbered in order of appearance, continuing from the numbering of issue boxes from the companion document published with this document, Plans for Developing Energy Conservation Standards for Battery Chargers and External Power Supplies. A complete list of the issues in these boxes are presented in the Appendices of each of these two documents.*

[1] Available for download in PDF format from DOE's homepage for BCs and EPSs: http://www.eere.energy.gov/buildings/appliance_standards/residential/battery_external.html

2. MARKET ASSESSMENT

2.1 INTRODUCTION

This section contains DOE's preliminary market assessment for BCs and EPSs. Section 2.2 describes trends in major consumer product categories and the manner in which they drive demand for BCs and EPSs. Section 2.3 highlights volume and price trends in the BC and EPS markets. Section 2.4 lays out the BC and EPS distribution network, including key categories of market actors and the relative importance of different channels. Section 2.5 identifies key manufacturers of BCs, EPSs, and the consumer products that use them, and identifies the industry associations that generally represent various groups of manufacturers in regulatory proceedings. Section 2.6 describes existing energy efficiency standards and programs and their potential impacts, as well as other programs that could impact the BC and EPS market. Finally, Section 2.7 contains a brief discussion of energy savings potential.

In preparing this preliminary market assessment, DOE made certain decisions about how it would classify the power conversion devices that are associated with consumer products. The Energy Policy Act of 2005 provided definitions for both a battery charger (BC) and an external power supply (EPS). DOE recently published a final rule notice on December 8, 2006 which adopted the EPCA definitions of a BC and an EPS without modification. 71 FR 71365-71366. EPCA defines "battery charger" as a "device that charges batteries for consumer products, including battery chargers embedded in other consumer products." (42 U.S.C. 6291(32)) EPCA defines "external power supply" as "an external power supply circuit that is used to convert household electric current into DC [direct current] or lower-voltage AC [alternating current] to operate a consumer product." (42 U.S.C. 6291(36))

While the EPCA definitions provide some clarity as to which devices should be classified as a BC and which should be classified as an EPS, DOE recognizes that there are many consumer products (e.g., laptop computers, video cameras, etc.) that incorporate both a BC and an EPS under the scope of the EPCA definitions. In these cases, DOE will have to determine whether these consumer products will be subject to two standards or whether a single standard can be applied with criteria developed to provide clear guidance as to whether the consumer product is classified as a BC or an EPS.

In addition to the direction under EPACT 2005 to hold a scoping workshop and conduct a determination analysis as to whether energy conservation standards are warranted for BC and EPS, DOE was also granted authority to establish two standards for one product that serves two major functions.[a] For some power converting devices, such as those powering laptop computers or hand-held video cameras, the power converter can both charge the battery and operate the consumer product, even if the battery is completely discharged or removed. These power conversion devices that perform two major functions (i.e., those functions of a BC and those functions of an EPS) could be classified as both a BC and an EPS. DOE is actively soliciting stakeholder comment on the issue of multiple standards for some consumer products. This issue is discussed in more detail in section 4 of this document.

For the preliminary market assessment presented in this section, DOE applied the ENERGY STAR classification structure to differentiate between a BC and an EPS. This classification structure essentially differentiates products on the basis of whether a consumer product that contains a rechargeable battery can operate with that battery removed (or fully

[a] As amended by section 135(c)(3) of EPACT 2005, EPCA 325(o)(5) now reads: "(5) The Secretary may set more than 1 energy conservation standard for products that serve more than 1 major function by setting 1 energy conservation standard for each major function." (42 U.S.C. 6295(o)(5))

discharged) while the power conversion device is connected. Consumer products that are able to operate under these conditions have their power conversion devices classified as EPSs. Those products that can only fully operate when the battery contains some partial charge, and are not able to operate with the battery removed and the power conversion device connected, are classified as BCs. DOE is soliciting comment on whether those consumer products that incorporate both a BC and an EPS under the EPCA definitions may be better classified in a third group of consumer products, in order to best structure its analysis for the determination.

DOE assembled this preliminary market assessment for early stakeholder review and comment. While DOE invites the public to comment on all aspects of this document, there are some particular data gaps and issues in the market assessment that are identified in Issue Boxes and that contain invitations for stakeholder input. DOE intends to revise and expand the market assessment in the coming months and publish a complete market assessment in conjunction with the Secretary's determination notice for these products. In addition, based on stakeholder comment during the Scoping Workshop comment period, DOE may also review and revise this initial classification structure of a BC and an EPS.

2.2 MAJOR CONSUMER PRODUCT GROUPINGS AND MANUFACTURERS

2.2.1 Overview

In general, the consumer products market drives the markets for BCs and EPSs. The relative importance of particular consumer product categories, with regard to the aggregate energy impacts of BCs and EPSs, depends on two factors: (1) the current and projected proportions of consumer products that ship with BCs or EPSs, and (2) the energy consumption of associated with BCs and EPSs.

Both sales and design of consumer products drive demand for BCs and EPSs. Sales volume is the primary driver, but trends in consumer product design also affect demand for BCs and EPSs. For some product categories, such as digital cameras, designers have a variety of choices when it comes to deciding how to power their products, including using a mains-powered BC or EPS, a universal serial bus (USB)-powered BC, or Power over Ethernet. However, in several key product categories, such as mobile phones and notebook computers, industry norms and consumer preferences constrain design choices.

Energy savings potential is a function of the aggregate annual average per-unit savings and sales volumes. DOE is continuing to develop the data necessary to calculate per-unit savings, but has a preliminary understanding of unit sales volumes and trends for EPS and for many consumer products from which EPS and BC sales can be inferred. To estimate BC and EPS sales from sales of consumer products, DOE used the ENERGY STAR criteria to differentiate between a BC and an EPS. As stated earlier, this initial classification is subject to revision, as DOE is soliciting stakeholder comment on how to classify devices that perform functions of both a BC and an EPS in section 4.

In terms of volume, the main consumer products that drive demand for BCs and EPSs are mobile phones, cordless phones, cordless power tools, notebook computers, and digital cameras. Increased demand for portability in the consumer electronics industry has driven demand for battery-powered products, which, in turn, has increased demand for both BCs and EPSs, as both are used to charge batteries in consumer electronics.

2.2.2 Consumer Products: Impact of Design on the Market for Battery Chargers and External Power Supplies

Manufacturer product design and consumer choice both impact the size and growth of the BC and EPS market. In some consumer product categories, nearly all models are powered the same way. For example, most handheld vacuums are powered by BCs while most flat-screen monitors are powered by EPSs. In other consumer product categories, the power conversion device can vary by manufacturer or model. For example, a hand-held video camera may operate with either a BC or an EPS, depending on its design.

An increasing number of portable devices can be recharged through a connection to a USB computer port. For example, one brand of portable digital music player, which represented a major percentage of the portable music-player market at the end of 2005, primarily charges its batteries with power from a USB port. It is also possible to charge such a portable digital music player by using an EPS purchased separately from the music player, but because most consumers of this device already have a computer with USB ports, most charging of these portable digital music players occurs through a USB port. The market trend toward consumer products that are USB-powered could impact the number of products that are shipped with stand-alone power conversion devices considered to be BCs and/or EPSs. A battery charger that uses power from a USB port could be considered a BC embedded in a consumer product under the statutory definition, although DOE recognizes that it may be difficult to accurately measure the power consumption of a USB-powered battery charger using the DOE's test procedure. In addition, DOE believes that the magnitude of the power consumed by these devices is likely to be relatively small compared with that of other portable consumer products. DOE invites stakeholder comment on the issue of USB-powered BCs.

Both technical issues and consumer preferences can influence manufacturer design choices. Technical considerations may relate to the method by which the device consumes power (e.g., short bursts of high current such as in a power tool or low levels of consumption, such as in a portable music player). Consumer preferences can also influence the design choice, such as having longer time between recharge or being able to operate the device from the mains power, and not having to wait for a battery to recharge. Variations in power system designs occur as manufacturers develop different design solutions to these problems.

This variance in design impacts the market. The shipments of a given type of consumer product in a given year does not necessarily correlate one-to-one with the number of BCs and/or EPSs that ship with those products. Technical issues and consumer preferences will influence manufacturer design choices, and sales of BCs and/or EPSs could decrease even as sales of total consumer electronics increase.

Issue 17: *DOE invites comment on whether BCs that use input power from USB ports should be included in the scope of this determination.*

Issue 18: *DOE invites comment on technical issues and consumer preferences that may drive market shifts toward or away from BCs and EPSs shipped with consumer electronics.*

2.2.3 Consumer Product Groupings that Use a Battery Charger and/or External Power Supply: General Trends

U.S. sales of consumer electronics and handheld appliances that are commonly sold with a BC and/or EPS have grown rapidly in recent years. According to the Consumer Electronics Association[1] (CEA) and Appliance Magazine,[2] 377 million consumer product devices using BCs and EPSs were sold in the U.S. in 2005, representing a 50 percent increase over sales in 2000. Growth in the telephony, computers and peripherals, visual entertainment, and camera groupings are the principal drivers in overall consumer electronics sales growth.

For a number of consumer product categories, DOE lacks the detailed data that would enable it to determine how many units are shipped with a BC and how many units are shipped with an EPS. In some categories, such as document scanners, some models have an internal power supply while others have an external power supply. Sales of document scanners, however, are reported without differentiation.

For the purposes of discussion at the Scoping Workshop, the Department prepared initial groupings of consumer products based on the ENERGY STAR definitions. These consumer products are classified into groups that use a BC and groups that use an EPS. Table 2.1 shows generally which product categories are included in each grouping. For EPSs, the table presents the typical maximum output power range. Figure 2.1 shows how sales in these product groupings have changed between 2000 and 2005. Estimates of output power are provided by market research published by the Darnell Group, Inc.[b] For BCs, as discussed in section 3.3 of

[b] The Darnell Group, Inc., is a market research and publishing firm that specializes in the power electronics industry.

the technology assessment, output power range does not necessarily correlate to energy savings opportunities, so wattage ranges are not given for products that use BCs in this table.

Table 2.1 Draft Consumer Product Groupings for Scoping Workshop						
Initial Product Groupings	**EPS Output Power Range**					
	<5W	5-10W	11-20W	21-50W	51-100W	>100 W
Household Appliances (BC)	Battery Chargers – Wattage Ranges Not Applicable					
• Portable Power Tools						
• Personal Care Appliances						
• Kitchen Countertop Appliances						
• Floor Care Appliances						
Cameras (BC and/or EPS)						
• Digital Cameras	■	■				
• Camcorders		■	■			
Visual Entertainment (EPS)						
• LCD TVs				■	■	■
• [*Plasma TVs*]						■
• Portable DVD Players		■	■	■		
Portable Audio (BC and/or EPS)						
• Portable Digital Music Players	■	■				
• Portable CD Players	■	■				
Computers & Peripherals (BC and/or EPS)						
• Notebook Computers					■	■
• Printers			■			
• Modems		■	■	■	■	
• Scanners			■	■		
• *[Flat Panel Monitors]*				■	■	
• PDAs	■	■	■	■		
• Word Processors and Electronic Typewriters			■	■	■	
• [*Wireless Local Area Network Access Points*]		■	■	■		
• [*Local Area Network Equipment*]		■	■	■		
• GPS Navigation Products	■					
Telephony (BC and/or EPS)						
• Mobile Phones	■	■				
• Cordless Phones	■	■				
• Telephone Answering Devices	■	■				
• Caller Identification Devices	■	■				

**Source for Power Range Data: Darnell Group, Inc., 2005.*
Note: Items in brackets and italics are products for which DOE currently lacks data. DOE recognizes that some of power conversion devices shipped with these products could be either a BC or an EPS, or could be classified as both a BC and an EPS. This issue is discussed in section 4 of this report.

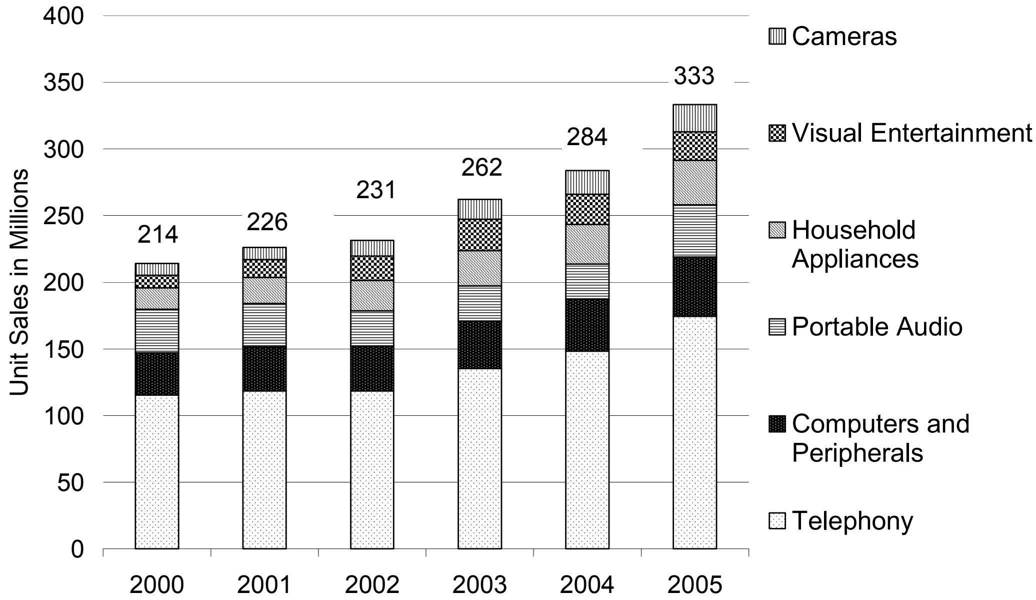

Figure 2.1 Unit Sales of Products Using a BC and/or EPS[c] by Grouping

Source: The DOE estimate based on U.S. Consumer Electronics Sales and Forecasts 2001–2006, *Consumer Electronics Association, January 2006; "Statistical Review,"* Appliance Magazine*, May 2006;* Darnell Group Inc., 2000 and 2005; Power Tool Institute 2006; and AHAM 2006.

Figure 2.2 shows forecasted unit sales growth, midpoint output power, and unit sales in 2005 of the initial consumer product categories discussed in the subsections below. Midpoint output power is the midpoint of the maximum power consumption ranges illustrated in Table 2.1. This figure illustrates the dynamics of the consumer products market and how it relates to sales of EPSs across a range of rated output power categories.

[c] Each consumer product included in this chart may be shipped either without a BC and/or an EPS, or be shipped with one or multiple BCs and/or EPSs. This chart does not include portable power tools, flat panel monitors, powered speakers, networking equipment, flatbed scanners, or gaming devices.

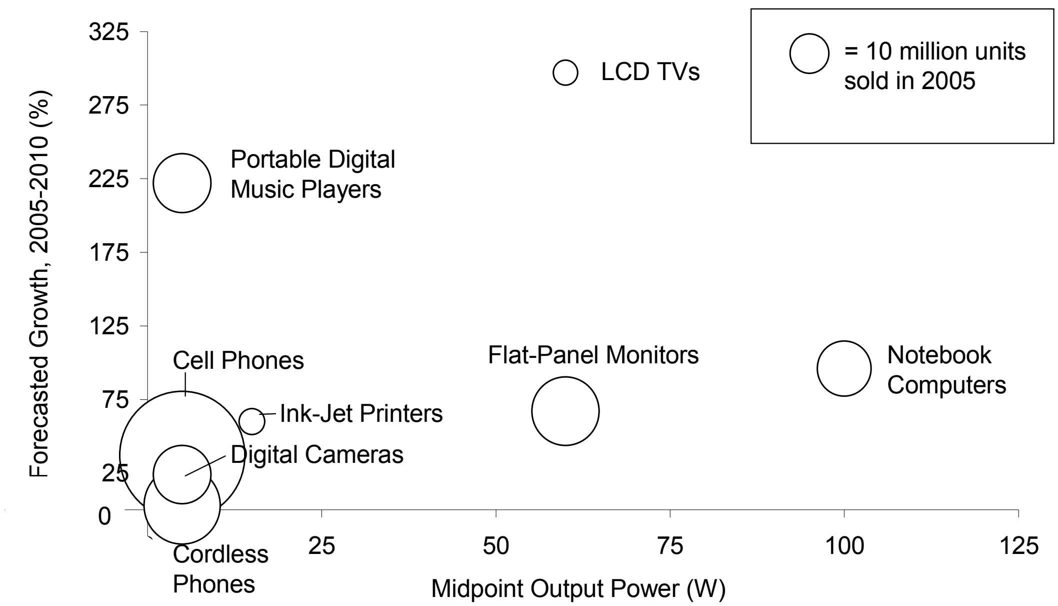

Figure 2.2 Forecasted Unit Sales Growth, EPS Output Power, and Units of Major Consumer Products Sold in 2005

Sources: Darnell Group, Inc., 2005; Consumer Electronics Association, 2006.

Note: This plot represents classification of EPS as per the ENERGY STAR definition of a BC and EPS. This initial classification of products may be revised for the determination analysis, based on stakeholder comment.

As Table 2.1 shows, EPSs shipped with specific consumer product groupings have nameplate output power ratings that fall within a continuous range. The larger a product's sales volume and rated maximum output power of the associated EPS, the larger impact it will have on total EPS power consumption. Output power consumption is not applicable to BCs, and for certain consumer product categories that use BCs, DOE currently lacks data on which to base discussion of the impact of consumer product sales.

The following sections of this report will highlight trends for leading products in each consumer product grouping. Growth in mobile phone sales has been the major driver of growth in shipments of EPSs under 10 watts (W). Growth in notebook computers, LCD TVs, and LCD computer monitors has driven sales growth in EPSs of 21 W and above. Growth in power tool sales could drive growth across a wide range of BC power-output categories.

The above analysis remains incomplete because specific sales data for some product groupings were not available. For others, it is not possible to determine the proportion of consumer product shipments in a grouping that are packaged with a BC and/or those packaged with an EPS.

Issue 19: *DOE invites comment on the initial consumer product groupings and ranges of maximum rated wattages of EPS shipped with those products. See Table 2.1.*

Issue 20: *DOE invites stakeholder comment on shipments of power tools, digital cameras, plasma TVs, flat-panel computer monitors, scanners, camcorders, printers, electronic musical instruments, hand-held global positioning system (GPS) receivers, and portable digital music players. DOE is also interested in understanding the type of power conversion system with which these products are typically sold.*

Issue 21: *DOE invites stakeholder comment on shipments between 2000 and 2005 for power tools, document scanners, LCD TVs under 23 inches, flat-panel computer monitors, portable digital video disc (DVD) players, electronic musical instruments, wireless local area network (LAN) and cord-connected local area network equipment, and portable gaming hardware.*

Issue 22: *DOE invites stakeholder comment on projected changes in shipments for products using a BC and/or an EPS, especially beyond 2010.*

2.2.3.1 Telephony (BC and/or EPS)

Mobile phones constitute the single largest grouping of consumer products sold with a BC and/or an EPS, with 124.8 million units projected to be sold in 2006. Sales of this product grouping grew 99 percent between 2000 and 2005. Mobile phones are now in an estimated 73 percent of U.S. homes.[1] Market penetration is now so high that the rapid growth of the last five years is expected to slow between 2005 and 2010. Sales are forecasted to grow 29 percent between 2006 and 2010.[3] Mobile phone batteries have a product life of about two years.[4] Since new mobile phones are usually offered with new contracts, which are about two years in length, consumers are becoming less inclined to purchase replacement phone batteries.[5] Although sales of mobile phones to first-time users may taper off, there should be continued demand for new mobile phones and, by extension, the BC and/or EPS required to operate those phones.

Another telecommunications technology, cordless phones, is expected to play an important but declining role in the market. While sales of cordless phones are large—unit sales in 2005 were 39 million—the market is considered by experts to be largely saturated. Household penetration stands at 88 percent and sales decreased slightly between 2000 and 2005.[1] Sales are forecasted to remain flat through 2010.[3] Despite the steady state of the cordless phone market, the number of BCs and/or EPSs shipped with cordless phones could continue to grow if an emerging trend toward packaging two or more cordless phone in a box. For these devices, an additional power adapter is provided with each cordless phone.

2.2.3.2 Computers and Peripherals (BC and/or EPS)

Computers and peripheral applications are especially important in the power conversion device market. High power products dominate computers and peripheral applications and, thus are a primary route of entry for high output power BCs and/or EPSs into the marketplace. Sales volumes for computers and peripherals are smaller than those for telephony, but with 44.5 million units sold in 2005, excluding document scanners and flat-panel monitors, sales are large nonetheless. Moreover, sales are forecasted to grow by 79.9 percent between 2005 and 2010. Printers, notebook computers, and flat-panel computer monitors are the largest product segments in terms of unit sales in the computer and peripherals grouping.

Printers are in the lowest power range in this grouping. Ink-jet printers generally use an EPS with nameplate output power between 11 and 20 W.[3] In 2003, Lawrence Berkeley National Laboratory (LBNL) estimated that 31 percent of ink-jet printers used in offices were shipped with an EPS.[6] Sales of ink-jet printers declined between 2000 and 2005 at a rate of 7.6 percent per year.[7] Sales of printers overall were almost completely unchanged over the same period,[1] implying that the drop in ink-jet printer sales is due to changes in preferences for particular types of printers. Sales of laser printers, which primarily use an internal power supply, grew 24 percent between 2000 and 2005.[2] Although ink-jet printers still constituted 63.5 percent of the printer market in 2005,[7] sales of EPSs for ink-jet printers are dropping as consumer preference shifts toward laser printers.

Notebook computers that use BCs and/or EPSs are part of the highest output-power range. In unit volume, notebook computers comprised 33 percent of the personal computer market in 2005, up from 17 percent in 2000.[7] While sales of desktop computers were relatively flat between 2000 and 2005, even decreasing during some years, sales of notebook computers increased by 137 percent.[7] Some industry analysts are forecasting that notebook computers will become 50 percent of the personal computer market by 2007.[8] This will increase the number of power conversion devices shipped, especially if the notebook is used as a substitute for a desktop computer.

Flat-panel monitors that use an EPS typically use one with output power between 21 and 100 W.[3] According to a survey conducted by LBNL in 2003, about 60 percent of flat panel monitors use an EPS.[6] This proportion is expected to decrease as screen sizes increase because larger flat-panel monitors tend to use an internal power supply.[9] At the same time, sales of all flat panel monitors are expected to grow 66 percent from 2005 to 2010.[3] These two trends will have countervailing impacts on the shipments of EPS devices with flat-panel monitors, making it difficult to project an overall trend for EPSs in this product subgroup.

2.2.3.3 Visual Entertainment (EPS)

The fastest-growing high power category in the visual entertainment grouping is LCD TVs.[1] Increasing screen sizes could decrease demand for EPSs in the 21–100 W range, but strong sales growth and low market saturation are likely to counterbalance that trend and lead to increased demand for EPSs in this output power range, at least through 2010.

Consumer demand for larger screens has the potential to increase power consumption associated with LCD TV EPSs. In general, LCD TVs less than 23 inches use an external power supply, and those with screen sizes above 23 inches use an internal power supply.[3] Average screen size is expected to grow from 23 inches in 2005 to 27 inches in 2007, meaning that more LCD TVs will be using internal instead of external power supplies.[10] However, growth in sales of LCD TVs is so strong that sales of LCD TVs with screens smaller than 23 inches are likely to grow nevertheless, thereby contributing to growth in factory sales of EPSs between 21 W and 100 W. The Consumer Electronics Association (CEA) estimated that LCD TV unit sales grew

383 percent between 2000 and 2005.[1] U.S. household penetration in 2006 was estimated at only 22 percent, compared to 98 percent for all types of TVs,[1] leaving plenty of room for additional growth in LCD TV sales.

2.2.3.4 Cameras (BC and/or EPS)

Digital cameras constitute a large and growing product type, but the number of digital cameras that use a BC and/or an EPS is unknown. Some digital cameras are sold with devices that plug directly into the camera and charge an integral battery. Others are sold with rechargeable batteries that are removed from the camera and charged in separate battery-charging holsters. Still others are designed to operate on standard sized alkaline batteries (e.g., "AAA" or "AA"), although these cameras may also be used with rechargeable batteries.

The digital camera market is likely to constitute a growing product grouping that requires study for understanding what type of device is used to power the camera. The digital camera market grew an estimated 423 percent between 2000 and 2005. With estimated household penetration in 2005 at 55 percent and new and improved models being introduced into the market every year,[1] the digital camera market has significant growth potential.

Issue 23: *DOE invites comment on the digital camera market, including proportion of shipments associated with the type of power conversion device supplied with the camera (if any).*

2.2.3.5 Household Appliances (BCs)

The household appliance grouping is made up of cordless rechargeable power tools and cordless rechargeable household appliances, the latter of which is further subdivided into kitchen appliances, personal care appliances, and floor care appliances. Cordless rechargeable power tools have experienced approximately 140% growth from 2000 to 2005,[11] while the cordless rechargeable household appliance market has experienced 21.4% growth during the same time period.[12] Because of the differential growth rates, the composition of the household appliance market has shifted; previously the majority of products using a battery charger were cordless rechargeable household appliances whereas now the majority are cordless rechargeable power tools.

Cordless rechargeable power tools are sold in a wide variety of classes, ranging from entry-level consumer tools intended for occasional homeowner use to high-end cordless rechargeable power tools designed for frequent use by professionals. As a result, these products use batteries with a wide range of voltages and have a variety of usage profiles. In general, BCs for professional cordless power tools probably spend more time in active mode than BCs for the homeowner, which spend the large majority of their time in non-active modes. .

Issue 24: *DOE invites stakeholder comment on the differences between homeowner and professional cordless power tool usage patterns.*

2.2.3.6 Portable Audio (BC and/or EPS)

Portable digital music players are the fastest growing product type in the portable audio grouping, but their impact on demand and distribution of BCs and/or EPSs is uncertain because designs are currently shifting toward USB charging which might not use a BC or an EPS. One major brand of portable digital music player has dominated sales in this grouping. However, like many other portable digital music players, it is charged via a computer's USB port. Consumers may choose to purchase a stand-alone BC and/or EPS to charge their portable digital music players, but since most users of these devices already have or have access to computers with

USB ports, the proportion of these portable digital music players is likely to be charged via the USB port. DOE is seeking comment from stakeholders on data or information pertaining to an estimate of how many portable digital music players are used with BCs and/or EPSs.

Increased sales of portable audio units may cause some increase in the total number of EPSs sold, but this increase will not be as large as the total increase in portable audio sales, which is expected to be over 200 percent between 2005 and 2010.[3] The market trend toward recharging these portable digital music players using USB ports may also spread to other consumer electronics, such as portable digital assistants (PDAs), thereby reducing the number of new stand-alone BCs and/or EPSs consuming power in the next 5 to 10 years.

Issue 25: *DOE welcomes input on the types of portable digital music players that use BCs or EPSs, historic data on shipments for 2000-2005, relevant design trends, and shipment forecasts.*

2.3 PRODUCT CHARACTERISTICS

2.3.1 Overview

In 2005, the total value of all EPSs[d] sold with consumer electronics in North America was estimated at $1.34 billion, representing 467 million EPS units shipped.[e] The North American market of consumer products shipped with EPSs is projected to grow approximately 57 percent between 2006 and 2010.[3] DOE continues to develop its estimate of the size of the BC market, as disaggregated, detailed shipment data are not immediately available.

[d] In this preliminary market assessment, DOE is using the ENERGY STAR definitions of a BC and an EPS to differentiate between the products. This initial classification of products may be revised for the determination analysis, based on stakeholder comment.
[e] While consumer electronics data is in terms of retail sales, EPS data is in terms of shipments.

DOE found that the available shipment data for these products tends to classify EPSs by output power rating and BCs by battery voltage, chemistry, and input power. This section discusses the market dynamics for these products based on those characteristics provided with the data. As discussed previously, for this preliminary market assessment, DOE is using its initial understanding of the difference between a BC and an EPS, as outlined in section 4.2.1.

When evaluating the energy performance of BCs and EPSs, the characteristics most frequently considered are the rate of energy consumption in maintenance mode (BCs only) and no-load modes (also referred to as "standby mode" for BCs), active mode efficiency, and technology type (e.g., unregulated, linear regulated, and switching regulated). These characteristics are important for understanding energy consumption. At present, data are available to characterize EPS models by output power, regulation type, efficiency in active mode, and power consumption in no-load mode.

2.3.2 External Power Supply Shipments

The primary data set available to assess EPS sales is the forecast published by the Darnell Group, Inc.,[3] which also includes some power conversion devices that DOE would consider to be BCs and are therefore outside the scope of coverage for EPSs. As a result, DOE has sought to include in its analyses only those consumer products that use a power supply that would be considered an EPS as per the ENERGY STAR definitions of a BC and an EPS, as discussed in section 4.2.1. Table 2.2 lists product categories in which at least some products are shipped with an EPS and for which the Darnell Group provides shipment data. Also indicated in Table 2.2 is the proportion of shipments in each category that are assumed to include an EPS, based on information currently available to DOE.

Table 2.2 Proportion of Products Shipped with EPSs in 2005

Product Category	Assumed Proportion that Shipped with EPS
Mobile Phones	100%
Cordless Phones	100%
Modems	100%
Handheld Computers	100%
LAN Equipment	100%
Notebook Computers	100%
Wi-Fi Access Points	100%
Portable Gaming Devices	100%
Small Flat Panel TVs	100%
Portable Video Players	100%
Flat Panel Monitors	80-100%
Flatbed Scanners	65-75%
Inkjet Printers	100%
Camcorders	100%
Digital Cameras	65%
Portable Audio Players	40%

Source: Darnell Group, Inc., 2005.
Note: This table represents classification of EPS as per the ENERGY STAR definition of a BC and EPS. This initial classification of products may be revised for the determination analysis, based on stakeholder comment.

Given the assumptions shown in Table 2.2, DOE estimates that some 467 million EPSs were shipped in 2005 for final sale in North America. Nearly three quarters of these units had rated output power less than or equal to 10 W. High volumes of mobile phone sales, which are approximately half of the EPS market, are the largest contributor to the abundance of EPS with these lower output powers.[3]

The market for EPSs is growing rapidly, with total sales expected to increase to over 700 million units by 2010. Linear growth is forecasted for all output power segments. However, shipments of EPSs with higher output power (>10 W) are forecasted to grow at a faster rate than shipments of EPSs with lower output power (≤10 W), as Figure 2.3 shows. The higher power segment is projected to grow 90 percent from 2005 to 2010, with the 51-100 W sub-segments doubling in size. It is estimated that by 2010, EPSs with output power >10 W will constitute 35 percent of EPS shipments and those with output power ≤10 W the remaining 65 percent, compared to 28 percent and 72 percent, respectively, in 2005. Growth in the higher power segment (>10 W) is primarily driven by projected growth in demand for LCD TVs less than 23 inches in size and notebook computers. Projected growth in the two lower power segments (0-5 W and 6-10 W) is driven primarily by growth in mobile phone sales.[3]

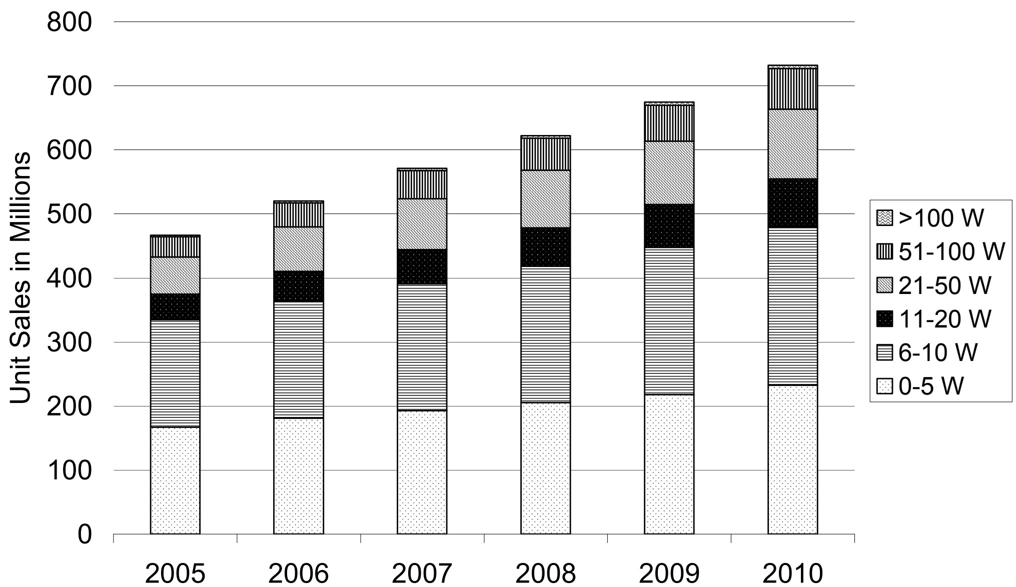

Figure 2.3 Forecasted Shipments of EPSs for Final Sale in North America by Output Power

Source: The DOE analysis of the Darnell Group, Inc., 2005.

Note: This plot represents classification of EPS as per the ENERGY STAR definition of a BC and EPS. This initial classification of products may be revised for the determination analysis, based on stakeholder comment.

Shipment data alone are insufficient to estimate energy consumption of EPS. Estimation of EPS energy consumption also requires knowledge of usage profiles for all major categories of consumer products that use EPS, as discussed in section 6 of *Plans for Developing Energy Conservation Standards for Battery Chargers and External Power Supplies*. As a first approximation, a comparison of estimated aggregate power capacity across power segments can show where the potential exists for the most energy consumption to occur. Note that a comparison of aggregate power capacities is only a rough indicator of energy consumption, given that EPSs do not, in practice, operate continuously at 100 percent of rated output power. Also, usage profiles vary greatly among power segments.

When EPS sales are evaluated from the perspective of aggregate power capacity, as shown in Figure 2.4, the higher power segments, despite their much smaller shipment volumes, contain more energy consumption potential than do the lower power segments, with their much larger shipment volumes. The total rated power capacity of all EPS units shipped in 2005 is approximately 7,600 megawatts (MW). In 2005, the two lowest power segments, 0 to 5 W and 6 to 10 W, together made up 72 percent of total shipments, but contained 21 percent of total EPS power capacity because each individual device draws relatively little power. In contrast, the two higher power segments, 21-50 W and 51-100 W, together made up 19 percent of total shipments yet contained 66 percent of total EPS power capacity. However, actual energy consumption and energy savings potential, which depends both on actual energy consumption and the relative potential for improvements in efficiency of EPS in each output power range, may or may not correlate with aggregate power capacity.

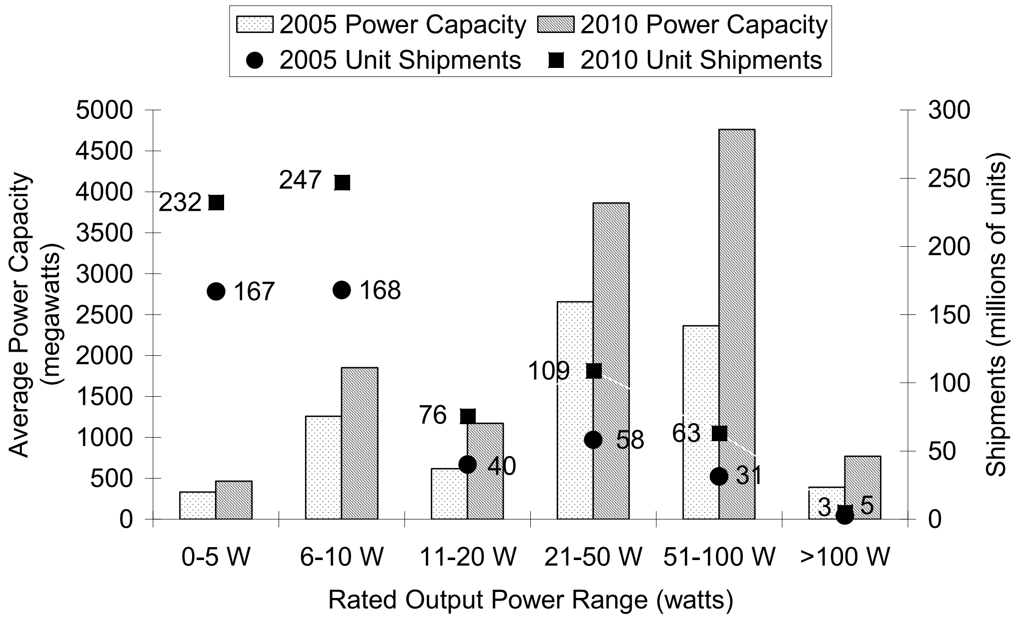

Figure 2.4 EPS Shipments Compared with Aggregate Output Power Capacity

Source: DOE analysis of the Darnell Group, Inc., 2005.

Note: This plot represents classification of EPS as per the ENERGY STAR definition of a BC and EPS. This initial classification of products may be revised for the determination analysis, based on stakeholder comment.

Voltage regulation type is another important characteristic of EPS. Details of the mechanics of the two major types of voltage regulation are described in section 3.2.2.2 of the technology assessment. As Figure 2.5 shows, three-quarters of EPSs shipped today use switching regulation, which is generally more efficient than linear regulation at higher wattages (>10 W). A number of market forces are expected to increase the market share of switching regulation to over 80 percent by 2010.

EPSs that incorporate switching voltage regulation are a large part of the EPS market at all output powers. The principal reason for the predominance of switching regulation is the demand for smaller and lighter EPS. These features are favored in applications for which portability is important, such as mobile phones, PDAs, and notebook computers. However, EPSs with switching regulation are more expensive than EPSs with linear regulation due to manufacturing differences between the two designs. Nevertheless, the market for switching EPS is forecast to grow 71 percent from 2005 to 2010.

Approximately one-quarter of EPS shipped today use linear regulation. Most linear EPS have rated output power <10 W and are used in low-power applications. Linear EPS are preferred in applications where price is the dominant factor, an extremely "low-ripple" output power is needed, or extraordinary resistance to power surges is required. The market for linear EPS is forecasted to grow 16 percent from 2005 to 2010.

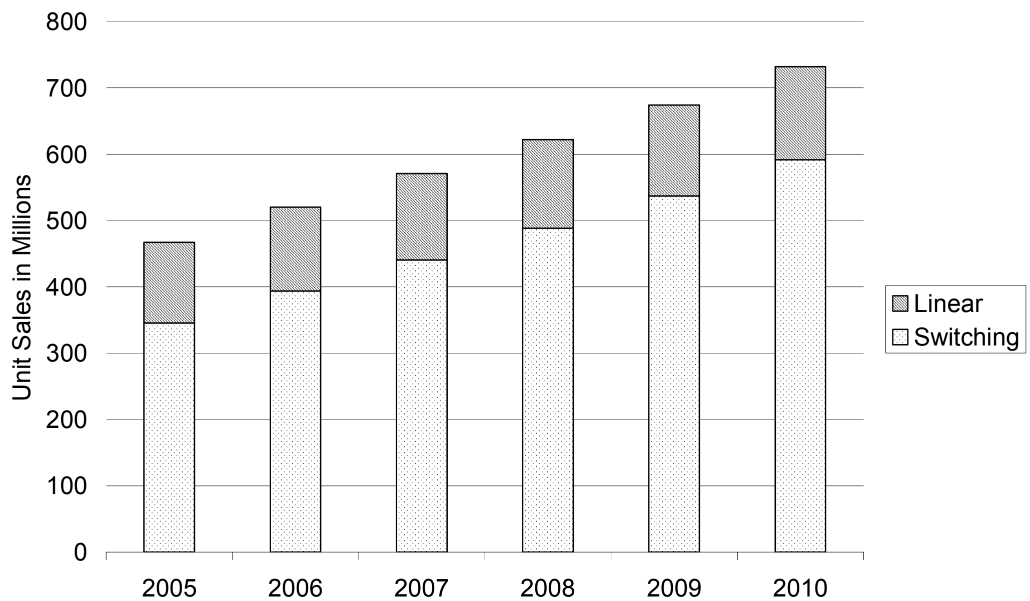

Figure 2.5 Forecasted Shipments of EPS for Final Sale in North America by Voltage Regulation Type

Source: The DOE analysis of the Darnell Group, Inc., 2005.
Note: This plot represents classification of EPS as per the ENERGY STAR definition of a BC and EPS. This initial classification of products may be revised for the determination analysis, based on stakeholder comment.

Issue 26: *DOE welcomes comment on the proportions of flat-panel monitors, flatbed scanners, printers, camcorders, digital cameras, and portable audio players that are shipped with BCs and/or EPSs.*

Issue 27: *DOE welcomes comment on how the respective market shares of linear and switching EPSs have changed historically.*

Issue 28: *DOE invites comment on usage patterns of consumer products that use a BC and/or an EPS.*

Issue 29: *DOE invites comment on forecasted growth of EPS shipments, particularly for the time period after 2010.*

2.3.3 Battery Charger Shipments

DOE continues to develop its estimate of the size of the BC market using sales of consumer products that use BCs in a manner consistent with the definitions of a BC in both the ENERGY STAR program[13] and section 135(a)(3) of EPCA (42 U.S.C. 6291 *et seq*.), as amended by EPACT 2005 (Pub. L. 109-58; EPACT 2005). However, this estimate is currently incomplete, as disaggregated, detailed shipment data are not immediately available. Stakeholders are invited to submit comments and information pertaining to current, historical, and projected future shipments of battery chargers. Stakeholders are also invited to comment on any trends in the market that may precipitate a change in battery charger shipments over time, such as the use of fuel cell technology into portable consumer products.

DOE has received historical shipment data from the Power Tool Institute (PTI) and the Association of Home Appliance Manufacturers (AHAM) for sales of cordless rechargeable power tools and cordless rechargeable household appliances, respectively. However, it lacks sufficient information to forecast future BC shipments because the percentage of some consumer electronics, such as digital cameras, shipped with a BC is unknown. DOE also lacks historical sales data on universal battery chargers and rechargeable batteries. Table 2.3 estimates the percentage of certain consumer products that may be assumed to ship with a BC.

According to both section 135(a)(3) of EPCA (42 U.S.C. 6291 *et seq*.), as amended by EPACT 2005 (Pub. L. 109-58; EPACT 2005), and the ENERGY STAR program,[13] some of the products in Table 2.3 may use BCs. For example, a cordless rechargeable shaver would always use a BC according to these definitions, while a digital camera may use a BC, an EPS, or replaceable batteries. These batteries, in turn, may or may not be rechargeable batteries that would use a universal battery charger. Because DOE lacks detailed information about consumer electronics device powered by BCs, it is unable to estimate the size of the BC market in this preliminary market assessment.

Table 2.3 Proportion of Products Shipped with BCs in 2005

Product Category	Assumed Proportion That Use BCs
Universal Battery Chargers	100%
Portable Audio	
• Digital Music Player	To be determined.
Cameras	
• Digital Cameras	To be determined.
• Camcorders	To be determined.
Cordless Rechargeable Power Tools	100%
Cordless Rechargeable Household Appliances	
• Personal Care Appliances	
o Cordless Rechargeable Shavers	100%
o Cordless Rechargeable Hair Clippers	100%
o Cordless Rechargeable Beard and Mustache Trimmers	100%
• Kitchen Countertop Appliances	
o Cordless Rechargeable Can Openers	100%
o Cordless Rechargeable Mixers	100%
o Cordless Rechargeable Electric Knives	100%
o Cordless Rechargeable Blenders	100%
• Floor Care Appliances	
o Cordless Rechargeable Stick Vacuums	100%
o Cordless Rechargeable Hand Vacuums	100%
o Cordless Rechargeable Robotic Vacuums	100%

Sources: AHAM 2006 and Power Tool Institute 2006

Issue 30: *DOE invites comment and data on historical and forecasted BC shipments.*

Issue 31: *DOE invites comment on future and historical shipments of universal battery chargers and the percentages of different consumer products that use a BC.*

2.3.4 Factory Prices

As with most products, the factory sales price of a BC or an EPS decreases as the purchased volume increases. And, those BC or EPS that are custom-designed, have more sophisticated features or have a higher output power tend to command higher prices, while lower power and less sophisticated devices (i.e., off-the-shelf, commodity designs) tend to have lower prices. Switching EPS generally are more expensive than comparable linear EPS, but the gap is narrowing as switching EPS are becoming less expensive. The average factory price of all EPS is forecast to decline slightly between 2005 and 2010.[3]

In the BC and EPS industry, the factory sales price[f] is the most important price, since most BCs and EPSs are part of a product when sold at retail. As Figure 2.6 shows, factory prices for units with higher output power are forecasted to decline between 2005 and 2010, but still remain higher than prices for units with lower output power, which are forecasted to decline only slightly over the same time period.[3]

[f] The factory sales price is the price at which the BC or EPS manufacturer sells the unit to an OEM, distributor, or retailer.

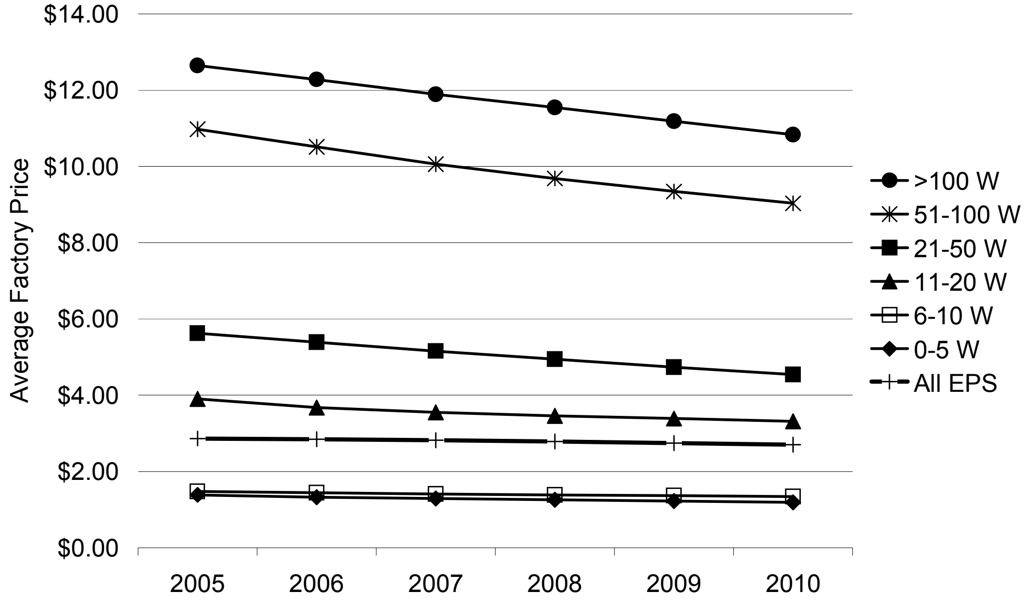

Figure 2.6 Forecasted Average Factory Prices of EPS in North America by Output Power Range, 2005-2010

Source: Darnell Group, Inc., 2005.
Note: This plot represents classification of EPS as per the ENERGY STAR definition of a BC and EPS. This initial classification of products may be revised for the determination analysis, based on stakeholder comment.

The average factory sales price for a switching EPS is approximately twice that of a linear EPS. While switching EPSs are generally more expensive than comparable linear EPSs, this large difference in average price is due in part to the fact that the market for linear EPSs is skewed toward devices with lower output power, which generally are less expensive than devices with higher power capacity.

Between 2005 and 2010, prices for switching EPSs are projected to decrease, while prices for linear EPSs are expected to increase slightly, as shown in Figure 2.7. Given the market dominance of switching EPSs, especially at higher output powers, these pricing trends are consistent with those for EPSs with higher and lower output powers.

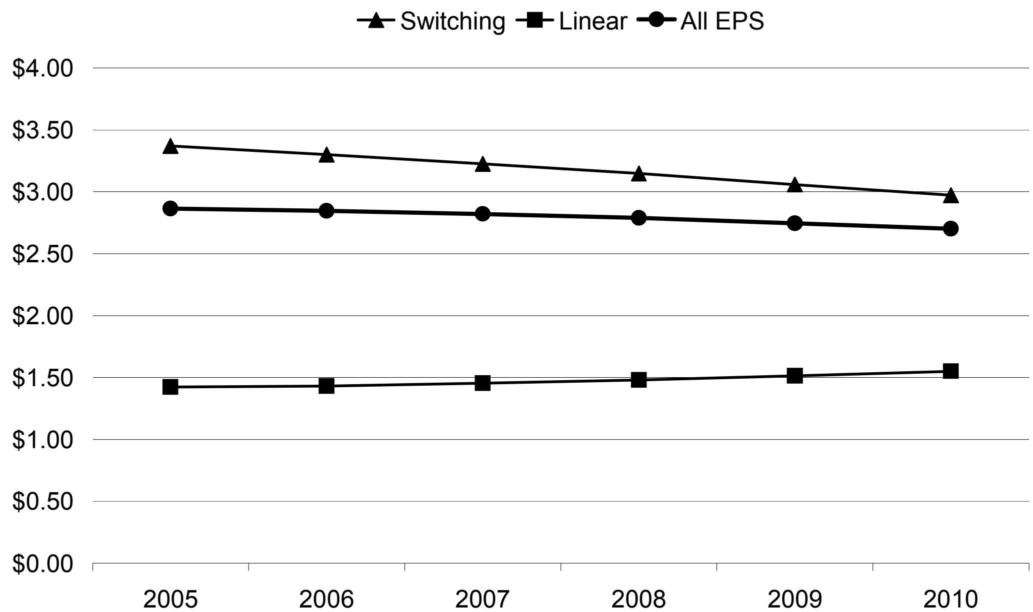

Figure 2.7 Forecasted Average Factory Prices of EPSs in North America by Regulation Type, 2005-2010

Source: The DOE Analysis of Darnell Group, Inc., data, 2005.
Note: This plot represents classification of EPS as per the ENERGY STAR definition of a BC and EPS. This initial classification of products may be revised for the determination analysis, based on stakeholder comment.

As BCs often are physically integrated into the end-use product, it is harder to track their factory prices. DOE lacks sufficient information about current or past BC prices to project future BC pricing trends.

Issue 32: *DOE invites stakeholder comment on factory prices of BCs by battery chemistry type and on retail prices of universal BCs. DOE also invites stakeholder comment on the factory prices and forecasted average factory prices presented in this section for EPSs.*

2.4 DISTRIBUTION CHANNELS

2.4.1 Overview

Distribution channels for BCs and EPSs can be most easily understood if viewed from two perspectives: order initiation and product delivery. Both of these processes are generally multinational in scope.

Original equipment manufacturers (OEMs) initiate the BC- and EPS-manufacturing process for the great majority of BCs and EPSs. An OEM contracts with a BC or EPS manufacturer to supply a device that meets the requirements of the OEM's consumer product. The BC or EPS manufacturer then designs and assembles the device from component parts. The large majority of EPSs and almost all BCs are customized and sold to the OEM. The remainder—stock products—is manufactured according to standard designs. Stock products are sold to OEMs, distributors, and retailers. They may be sold separately, as in the cases of aftermarket replacement EPSs or universal BCs, or they may be bundled with a consumer product that does not require a custom-designed BC or EPS.

The BC and EPS distribution networks are complex. Figure 2.8 shows the physical distribution network, which starts with component manufacturers. Component manufacturers send their components to BC or EPS manufacturers, who in turn ship their devices to retailers, distributors, and OEMs. A distributor may ship a BC or an EPS to either an OEM or a retailer. An OEM packages the BC or EPS with a consumer product, such as a cell phone, and ships the entire package to the retailer, who sells it to the consumer.

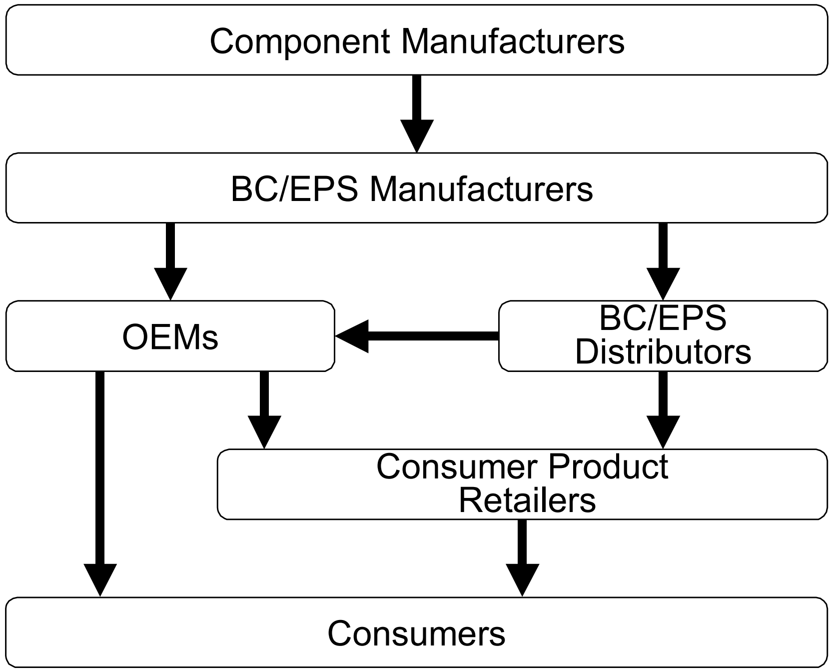

Figure 2.8 BC/EPS Product Distribution Network

Sources: Calwell and Reeder, Manufacturer Incentives for Energy Efficient Power Supplies 2002; Calwell and Reeder, Power Tools: A Hidden Opportunity for Energy Savings, 2002; Collon Lee, Astec Power, Personal Communication, 2006; Michael O'Connor and Michael Mueller, Phihong USA, Personal Communication, 2006.

2.4.2 Manufacturers

Three types of manufacturers are involved in the BC and EPS distribution network: component manufacturers, BC and EPS manufacturers, and OEMs.

Component manufacturers include manufacturers of transformers, diodes, capacitors, semiconductors, and other BC and EPS parts. Some companies manufacture both components and complete EPS devices. Components are manufactured both in the U.S. and abroad.

Component manufacturers supply BC and EPS component parts to BC and EPS manufacturers, who assemble the components into complete BCs and EPSs. The vast majority of BCs and EPSs are manufactured in East Asia, and especially in China and Taiwan.[3] After a BC or EPS is manufactured, it is delivered to a retailer, distributor, or OEM.

Many OEMs order large volumes of custom-designed BCs or EPSs direct from the manufacturer. This initially is more expensive than purchasing off-the-shelf models, but this practice enables an OEM to procure BCs and EPSs that exactly fit the requirements of its specific consumer-product models, and is cost-effective for large-volume sales.[14]

The vast majority of OEMs sell their products exclusively through retailers. However, a small number sell directly to consumers, usually through online sales. This is most common in the computer industry, where some manufacturers allow consumers to purchase computers assembled to their specifications. Hence, some EPS for notebook computers are sold directly from OEMs to consumers.

2.4.3 Distributors

Manufacturers of BCs and EPSs sell fewer BCs and EPSs to distributors than they sell directly to OEMs. The BCs and EPSs shipped through distributors tend to be stock products sold in small volumes.[14] These, in turn, are purchased by smaller OEMs that cannot purchase the large volumes needed to make customized designs cost-effective. Distributors also serve as a conduit between manufacturers and retailers for universal BCs and replacement EPSs.

2.4.4 Retailers

Manufacturers of BCs and EPSs sell fewer BCs and EPSs directly to retailers than they sell to OEMs. Products sold directly to retailers are primarily universal BCs and replacement EPSs, which are sold separately from the consumer products that they power. Universal BCs can be used in combination with a wide variety of consumer electronics that accept both primary and rechargeable batteries, including digital cameras and GPS receiver units. Universal BCs can now be found in many grocery stores. Grocery store sales of BCs grew by almost 50 percent from 2004 to 2005.[15]

Retailers are the main point of contact with consumers within the distribution network. Except when the BC or EPS is sold separately, the consumer product of which the BC or EPS is a component is the focal point of the sale, and the BC or EPS itself is of secondary importance to the consumer.

2.5 MANUFACTURERS

2.5.1 Manufacturer Associations

Two major trade associations represent EPS manufacturers, and five major trade associations represent manufacturers of consumer products that use BCs and EPSs. There is no major trade association that represents BC manufacturers. These associations generally represent the industry in regulatory and legislative proceedings and are frequently the best sources of accurate information about the markets for their products.

As Table 2.4 outlines the different organizations and the industries or regions they represent. There are two primary associations for EPS manufacturers, the Power Sources Manufacturers Association (PSMA)[16] and the European Power Supply Manufacturers Association (EPSMA).[17] Some PSMA and EPSMA member companies also manufacture BCs. Although they represent the same industry, the PSMA is the primary representative of EPS manufacturers in the U.S., and the EPSMA is the primary representative of EPS manufacturers in Europe. There is some overlap in membership in consumer product associations because some members have subsidiaries in different industries. The Association of Home Appliance Manufacturers (AHAM)[18] represents the home appliance industry, and works closely with the Power Tool Institute (PTI).[19] The CEA[20] represents the large and varied consumer electronics industry. The Information Technology Industry Council[21] and CTIA: The Wireless Association[22] focus on information technology and mobile communications, respectively.

Table 2.4 Major Trade Associations of Consumer Product Manufacturers

Manufacturer Association	Examples of Major Member Manufacturers	Major Consumer Product Categories Represented
Power Sources Manufacturers Association (PSMA)	Artesyn, Astec, Ault, Cherokee, China Power Supply Society, Emerson Energy Systems, Leader Electronics, Power Integrations	Not applicable
European Power Supply Manufacturers Association (EPSMA)	Artesyn Technologies, Astec Europe, Cherokee, Delta Electronics, Efore, FRIWO Power Solutions, Lambda Europe, MagnaTek, Roal Electronics	Not applicable
Association of Home Appliance Manufacturers (AHAM)	Black & Decker, Bosch, Emerson, GE, Hoover, LG, Panasonic, Philips, Samsung	Hand-held vacuums, power tools, personal care products
Power Tool Institute (PTI)	Black & Decker, Bosch, DeWalt, Hitachi, Milwaukee, Ryobi, Makita	Power tools
Consumer Electronics Association (CEA)	Apple, Bose, Canon USA, Daewoo, Energizer, Epson, Dell, Garmin, HP, JVC, Kodak, LG, Mitsubishi, Nokia, Panasonic, Philips, Radio Shack, Ricoh, Samsung, Sanyo, Sony, Toshiba, Tyco	Portable audio, notebook computers, digital cameras, stand-alone battery chargers, printers, portable navigation, other consumer electronics
Information Technology Industry Council (ITIC)	Apple, Canon, Cisco, Dell, Kodak, HP, Lenovo, Lexmark, Microsoft, Panasonic, Sony, Texas Instruments	Notebook computers, printers, digital cameras
CTIA: The Wireless Association	Ericsson, HP, Kyocera, Motorola, Nokia, OnStar, Samsung, Siemens, Texas Instruments	Mobile phones, portable and transportable navigation, other wireless communication products

Source: PSMA, EPSMA, AHAM, PTI, CEA, ITIC, and CTIA websites, 2006.

2.5.2 Battery Charger and External Power Supply Manufacturers

2.5.2.1 Overview

Manufacturers of BCs and EPSs include manufacturers of only BCs, manufacturers of only EPSs, and manufacturers of both. In its initial analysis, DOE identified 128 manufacturers of BCs and/or EPSs headquartered in the United States.[23] These manufacturers are listed in Appendix B. Despite large fragmentation in the BC and EPS markets, Darnell's analysis shows that ten manufacturers control almost half of the global market.[3] The Darnell report also claims that almost all BCs and EPSs are manufactured in East Asia, especially in China and Taiwan.

Issue 33: *DOE invites comments on names, quantities, and manufacturing activities of BC and EPS manufacturers worldwide.*

2.5.2.2 Global Market Share and Level of Customization

The top ten BC and EPS manufacturers received almost half of the global BC and EPS revenues in 2005, as shown in Figure 2.9. The majority of revenue to the top EPS manufacturers comes from high-volume sales (above 10,000 units each) of customized switching EPSs for telecommunications and computers and peripherals, although many top EPS manufacturers make linear EPSs as well.

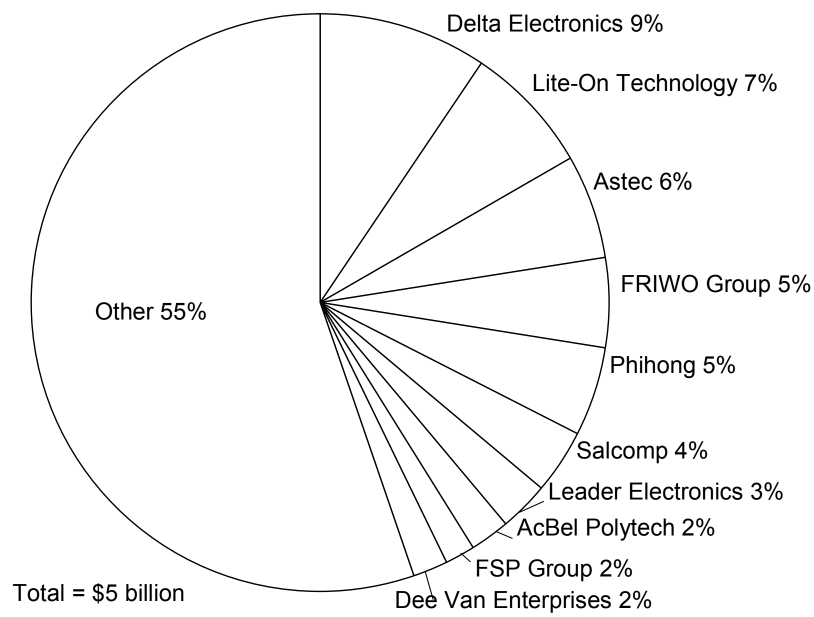

Figure 2.9 BC/EPS Manufacturer Share of Global Revenues (2005)

Source: Darnell Group, 2005.

Larger EPS manufacturers produce high volumes (more than 5 million units per month) of customized EPSs. Smaller EPS manufacturers, who make up the majority of manufacturers, produce low volumes (1 to 5 million units per month) of off-the-shelf EPSs.[3]

Unlike EPSs, almost all BC units are customized for the end-use product and battery chemistry. Designing a BC for certain battery chemistries, such as lithium ion (Li-ion), may require more customization than designing a charger for other battery chemistries, such as nickel cadmium (NiCd). A higher degree of customization means that a given BC can only safely charge the battery chemistry it is designed to charge, and not others. This makes manufacturing a BC more design-intensive than manufacturing an EPS.

2.5.2.3 Location

Multinational firms, defined as companies with non-manufacturing facilities in more than one country,[g] dominate BC and EPS manufacturing. Multinationals must navigate through a variety of regulatory structures worldwide, and this may increase overall costs. Differing regulations in different countries can force multinationals to produce a variety of BC and EPS products to meet varying energy performance requirements.

DOE has identified 143 BC and EPS manufacturing firms that are headquartered in the U.S. These companies may be either multinational companies or BC and EPS manufacturing firms with operations only in the U.S. A list of manufacturers that DOE has identified is available in Appendix B.

DOE has identified at least 21 other countries in which BC and EPS manufacturers are headquartered. China is the leading manufacturer of BCs and EPSs and is itself a growing consumer of products that incorporate these devices. The BC and EPS market is a global industry with a high level of fragmentation among manufacturers, but also a degree of concentration of market power among a small number of larger companies.

2.6 OTHER REGULATORY AND VOLUNTARY PROGRAMS AND THEIR POTENTIAL IMPACTS

2.6.1 Overview

A number of programs designed to increase the energy efficiency of BCs and/or EPSs have been established or are under development in the U.S. and internationally. Nearly all

[g] The definition of multinational firm used here excludes manufacturing operations from consideration. If manufacturing operations were included, almost all firms would be considered "multinational" because almost all BCs and EPSs are manufactured in East Asia, and especially in China. The term would not accurately denote which manufacturers truly have a multinational presence.

programs are closely based on or are moving toward harmonization with the requirements of the voluntary ENERGY STAR program, developed by the EPA. Programs to regulate cadmium also may have indirect effects on BC energy efficiency. The scopes of different programs' BC and EPS definitions are outlined in section 4.2.2.

Eight States in the U.S., representing one quarter of the U.S. population, have adopted mandatory efficiency standards for EPSs. These standards are based largely on the ENERGY STAR program for EPSs, but in a way that extends coverage as EPSs to some devices considered BCs by the ENERGY STAR program. All of these standards, scheduled to take effect within the next two years, have the potential to transform the U.S. market, and thereby increase the overall efficiency of EPSs.

Furthermore, there is growing interest in establishing mandatory energy conservation standards outside the U.S. Australia and New Zealand have such programs in place, while the European Union (EU) and Canada are considering them. Should the EU adopt such a program, it could, in combination with efforts by the eight States in the U.S., transform the world market for EPSs.

2.6.2 Programs in the United States

The only nationwide efficiency programs for BCs and EPSs are the voluntary BC and EPS ENERGY STAR programs. The BCs that meet the non-active energy ratio requirements in *ENERGY STAR Program Requirements for Products with Battery Charging Systems*[13] and the EPSs that meet the minimum energy efficiency and no-load power consumption requirements in *ENERGY STAR Program Requirements for Single Voltage External Ac-Dc and Ac-Ac Power Supplies (Version 1.1)*[24] qualify for the ENERGY STAR label.

The ENERGY STAR program's voluntary requirements have become the basis for a several mandatory EPS energy efficiency standards at the State level. To date, eight States have enacted mandatory energy efficiency standards for EPS, as classified by the ENERGY STAR definition of an EPS. However, none of these States have adopted the exemption for BCs from the EPS standards, as was done by ENERGY STAR. Therefore, these States have enacted EPS standards that apply to power conversion devices that would otherwise be classified by ENERGY STAR as BCs. Standards for EPSs are due to take effect in 2007 in California[25] and Oregon,[26] and in 2008 in Arizona,[27] Massachusetts,[28] New York,[29] Rhode Island,[30] Vermont,[31] and Washington.[32] When these standards take effect, they will require that all EPSs sold in those States meet the minimum energy efficiency and maximum no-load power consumption requirements given in *ENERGY STAR Program Requirements for External Power Supplies (Version 1.1)*.[24] Legislation for EPS standards is pending in Illinois[33] and Hawaii.[34]

The ENERGY STAR EPS program requirements do not apply to some consumer product types covered under State standards. For example, a handheld vacuum that is sold with a separable external power adaptor would have to meet the BC program requirements in order to qualify for the ENERGY STAR label, but would be subject to the mandatory standards for EPSs in States with EPS standards. Although no State has yet enacted standards for BCs, this issue is being studied in California, which has published draft standards on BCs.

Approximately one quarter of the U.S. population lives in the eight States with EPS standards slated to take effect in 2008. Assuming that per-capita consumption of consumer products that use BCs and EPSs is nearly uniform across the U.S., energy conservation standards in these eight States have the potential to make a significant impact on the U.S. market as a whole. Figure 2.10 and Table 2.5 summarize these States' standards.

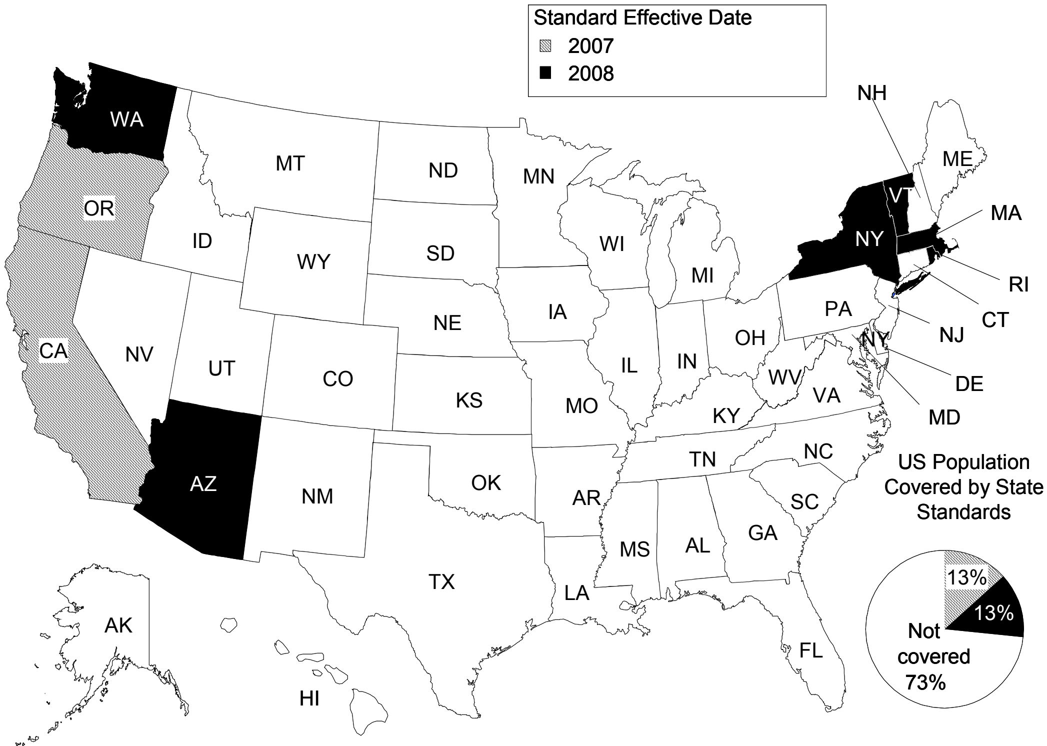

Figure 2.10 States Adopting EPS Standards

Source: The DOE Analysis of Information Provided by StateScape, State legislatures, and the California Energy Commission.

Table 2.5 State Energy Efficiency Standards for EPS

State	Date Standard Takes Effect	Share of U.S. Population in 2005
California	Jan. 1, 2007 and July 1, 2007*	12.2%
Oregon	Jan. 1, 2007	1.2%
Arizona	Jan. 1, 2008	2.0%
Massachusetts	Jan. 1, 2008	2.2%
New York	Jan. 1, 2008	6.5%
Rhode Island	Jan. 1, 2008	0.4%
Vermont	Jan. 1, 2008	0.2%
Washington	Jan. 1, 2008	2.1%
Total		26.8%

** The California standard for EPS used with notebook computers, mobile phones, printers, printer servers, scanners, PDAs, and digital cameras will become effective on January 1, 2007. The standard for EPS used with all other products will become effective on July 1, 2007.*
Sources: StateScape and State legislatures, 2005-2006; U.S. Census Bureau, 2005.

The new State standards are expected to further increase demand for switching EPSs, which tend to be more efficient than linear EPSs. They may also encourage manufacturers to use internal power supplies to avoid efficiency standards for EPSs.

The new State standards may affect the BC market as well, although the possible extent of this effect is unclear. Some external AC-DC power adaptors operate as components of BCs, in which the power adaptor is separate from the charger base. Such power adaptors would be regulated under all of the State standards for EPS. Under the ENERGY STAR program external power adaptors for BC are specifically excluded from EPS standards and treated as BC. However, no such exclusions exist in the present State standards. While the ENERGY STAR program specifications for BCs and EPSs were in development, many industry representatives voiced concern over regulating BCs in active mode, since most BCs spend such a small amount of time in this mode. For this reason, the ENERGY STAR specifications specifically address maintenance and no-load (standby) modes.[h] State standards regulating BCs in active mode may lead manufacturers to produce BCs with high efficiency in active mode, to the detriment of efficiency in maintenance mode, but without a meaningful reduction in energy consumption.

State regulations that prohibit sales of cadmium, a key ingredient in NiCd rechargeable batteries, also have the potential to affect BC and EPS markets. Because NiCd batteries are the least expensive type of rechargeable battery, these regulations may increase product prices as products would be required to use different and presumably more expensive battery technology. Although no state has yet passed laws prohibiting the sale of cadmium, state legislatures in Maine,[35] New Jersey,[36] Rhode Island,[37] and Vermont[38] have recently introduced legislation that would ban the sale of cadmium in their jurisdictions. Although the bills did not pass, they have raised concern among some manufacturers of NiCd batteries.

Issue 34: *DOE requests comment on the impact of various State standards and regulations on the market for BC and EPS.*

2.6.3 Programs Outside of the United States

The EU, China, and South Korea have all created voluntary labeling programs for EPSs. Australia and New Zealand have a mandatory standards program for EPSs. The Australian and New Zealand standard programs specifically exclude BCs, which are not covered by any efficiency standards program. Canada is considering developing mandatory standards for BCs or EPSs. All of the programs mentioned in this paragraph are, or probably will be, based on the ENERGY STAR program.

[h] For more information on the ENERGY STAR test procedures, which DOE proposed to adopt as its test procedures for BCs and EPSs, see section 1.3 of *Plans for Developing Energy Conservation Standards for Battery Chargers and External Power Supplies.*

The EU program[4] varies slightly from the ENERGY STAR program. The EU defines more EPS product classes than does the ENERGY STAR program, and provides standards only for those products with output power between 0.3 W and 150 W. The EU's voluntary EPS specifications for active mode will be largely harmonized with the ENERGY STAR program after January 1, 2007. The EU Code of Conduct will only provide standards for products with output power up to 150 W, while the ENERGY STAR program provides specifications for products with output power up to 250 W. The no-load mode requirements will continue to differ and thus provide specifications for four product classes, in contrast to ENERGY STAR's two product classes.

China has a voluntary labeling program for EPSs that excludes BCs, and certifies EPSs that fulfill the same requirements as ENERGY STAR-qualified EPSs. China does not have a labeling program for BCs.[39]

South Korea has a voluntary labeling program both for BCs and EPSs, but there are large differences between the South Korean and ENERGY STAR programs. The South Korean program has a voluntary EPS no-load specification for different input power ranges and a voluntary BC no-load specification for all BCs. However, South Korea defines BC differently than ENERGY STAR does. The South Korean BC no-load specification applies specifically to wireless and cordless phones, two product types that are defined under the ENERGY STAR program as using EPSs.[5]

Australia and New Zealand are the only countries that are implementing mandatory EPS standards. As of October 1, 2007, all EPS with nameplate output power less than 250 W and sold in Australia and New Zealand must comply with the same requirements as the ENERGY

STAR specifications. This standard excludes BCs. Also, Australia and New Zealand have a voluntary "high-efficiency product" label for products that meet more stringent energy efficiency criteria.[40] As Australia and New Zealand's energy conservation programs have not yet gone into effect, it is difficult to know what subsequent effect they will have on the global EPS market.

The Canadian government initiated a process to develop a test procedure for measuring the energy efficiency of BCs and EPSs in 2006. The Canadian Standards Association (CSA) is managing this process. The CSA used the ENERGY STAR test methodologies for both BCs and EPSs as a starting point. The CSA expects to communicate a proposed test procedure in mid 2008. The Canadian government also is planning to evaluate minimum performance energy conservation standards for BCs and EPSs. Once a test procedure is in place, Natural Resources Canada (NRCan) will conduct a technical and economic analysis to determine if regulatory standards are necessary and appropriate for Canada. Further, NRCan anticipates that its analysis on a proposed minimum performance level will be published in 2008, with a final decision establishing minimum performance standards scheduled for 2009.

Programs outside the U.S. are unlikely to have much effect on the global BC market because mandatory programs explicitly exclude BCs, while those programs that include BCs under an EPS standard are voluntary.

2.7 POTENTIAL ENERGY SAVINGS

As noted in Section 1, DOE is required to include as part of its assessment of the current and projected future market for BCs and EPSs "estimates of the significance of potential energy savings from technical improvements to battery chargers and external power supplies." (42

U.S.C. 6295(u)(1)(C)(i)) DOE interprets this requirement as an estimate of national energy savings potential for BCs and EPSs. DOE developed a preliminary estimate as part of its priority setting for FY 2005: 1.8 quads over the 2010 to 2035 period.[41] In preparing this estimate, and to be consistent with how DOE prepared estimates for all products included in the priority setting analysis, several simplifying assumptions were made. For example, the respective markets for these products and the devices they power were assumed to be constant size over time. In addition, it was assumed that "80 percent efficient power supplies were used in all applications," and potential efficiency improvements in the absence of regulation were not considered.

DOE is developing, as part of its determination analysis, a more robust estimate of energy savings potential for BCs and EPSs. These new estimates will take into account potential future changes in market size and unit energy consumption of new BCs and EPSs over time. For more information about how DOE plans to develop its estimates of national energy savings potential, see the discussion of the national impact analysis (Section 10) contained in *Plans for Developing Energy Conservation Standards for Battery Chargers and External Power Supplies*.

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3. TECHNOLOGY ASSESSMENT

3.1 INTRODUCTION

BCs and EPSs are power converters that convert mains power to power in a form useful to a battery or consumer product. Not all of the input power is converted to output power; the BC or EPS consume some of the input energy and pass the rest of the energy on to the battery or consumer product. Even when the BC or EPS is not connected to a battery or consumer product, the power converter still consumes energy if it is connected to mains.

It is important to distinguish between the devices the user sees as a BC, EPS, battery or consumer product versus the internal circuits that provide functionality. For the purposes of this technology assessment, the fundamental internal circuits are presented in their most simplified forms. For an EPS, the fundamental circuits consist of the raw supply and a regulator. The groups of functional circuits within the consumer product are referred to as loads and collectively referred to as "the load." For a BC, the fundamental circuits consist of a raw supply, charging regulator, and rechargeable battery. Other circuits that are not critical to the technology assessment because they do not increase performance or energy efficiency, such as an emissions filter, are not discussed in this section.

Although BCs and EPSs both convert mains power, energy-savings opportunities arise from three different modes of operation: no-load mode, maintenance mode, and active mode. A BC or an EPS operates in no-load mode when the BC or EPS is connected to the mains, but not when it is connected to a battery or a separate load. A BC operates in maintenance mode when the battery is fully charge but remains connected to the charger, which is connected to the mains.

A BC or an EPS operates in active mode when the BC or EPS is engaged in charging a battery or operating a consumer product.

This technology assessment will examine why BCs and EPSs consume energy and how to improve their efficiency. To enable the reader to understand the potential for technological improvements, this technology assessment presents a tutorial of BC and EPS technology broadly at first, becoming more specific in each subsequent section, and finally ending with a review of efficiency improvement opportunities. First, to establish context, section 3.1 discusses different applications of BCs and EPSs and their corresponding consumer products. In section 3.2, the various functions of EPSs are examined. Section 3.3 introduces BC systems, building off previously covered EPS concepts.

Section 3.4 presents potential improvements to BC and EPS efficiency. For BCs and EPSs, efficiency is inherently tied to their modes of use and the efficiency improvement opportunities available in each mode. For EPSs, the greatest potential efficiency increase is found by improving the quality of the EPS component parts with the greatest losses. The quality of component parts is also a key aspect of BC efficiency improvements. However, the largest increases in BC efficiency come from reducing BC energy consumption when the BC is delivering little or no power to the battery.

3.2 EXTERNAL POWER SUPPLIES: MAINS ISOLATION, POWER CONVERSION, AND REGULATION

When an EPS converts power from the mains to become power useful to the load, it also provides two critical safety functions. First, it isolates end-users from the mains power, and second, it converts mains voltage to a lower voltage. The raw supply, a circuit within the EPS, sometimes serves these functions.[a] Mains power can deliver a dangerous or even lethal shock. To reduce shock hazards, the raw supply electrically isolates end users from mains power by eliminating a direct electrical path between the mains power and the end user. Electrical isolation ensures that end users cannot accidentally become part of a circuit between the mains and the ground, which could cause serious injury. The raw supply also reduces the mains voltage to a voltage that is safe for consumers, either less than or equal to 30 volts root-mean-square alternating-current (V RMS AC) or less than 60 volts direct-current (V DC)[b]. Underwriters Laboratories (UL) certification for EPSs requires mains isolation and establishes a maximum voltage output. Therefore, all EPSs must provide this safety function either in the raw supply or in another circuit.[c] In providing this necessary functionality, the EPS consumes energy and lowers its efficiency.

In addition to safety, the raw supply converts mains power at 120 V RMS AC to lower voltage AC or DC to meet the load's power requirements. However, the voltage output of the raw supply is not necessarily stable: variations either in the mains power or the resistance of the load in the connected consumer product can result in fluctuations in the raw supply output voltage. These fluctuations can cause the consumer product to malfunction or even to stop working. An explanation of the raw supply circuit, and why it may have fluctuating output voltages, is discussed in Section 3.2.2.

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[a] The raw supply provides the safety functions in an unregulated EPS or a linear regulated EPS. For a switching regulated EPS, the regulator circuit provides safety requirements.
[b] The RMS voltage is the peak AC voltage divided by $\sqrt{2}$.
[c] Isolation and safe voltage requirements from UL Standards 1310 and 60950-1.

Another design consideration for EPS, as well as BC, is power factor.[d] The lower the power factor, the greater the current required per watt of power. The power distribution system capacity and its associated power losses are affected by this current demand. Improving the power factor of an EPS from the typical 0.5 to 0.7 range to a higher level may slightly reduce EPS efficiency, but will increase the overall efficiency of the power distribution system. Improving or correcting the power factor has a greater impact on efficiency for EPSs with higher output power ratings, such as 100 W and larger.

Figure 3.1 shows the interaction between the mains, the EPS, and its raw supply, and the connected consumer product and its loads. Mains power passes through the EPS, where the power is converted and isolated in the raw supply circuit. The EPS then provides the converted power to the consumer product, which distributes this power to the loads as the user operates the product. This technology assessment will provide a tutorial of fundamental EPS circuits and the functions they serve. Based on the information in the tutorial, changes to the EPS circuits which provide similar functionality but have improved efficiency will be presented.

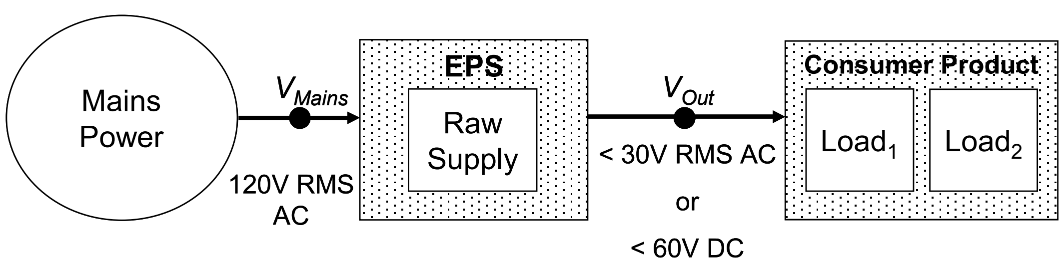

Figure 3.1 Mains Power, EPS, and Its Raw Supply; and the Consumer Product and Its Loads

Note: Optional regulator circuit is not shown

[d] Power factor is the ratio of the active power in W to the apparent power in volt-amperes. Harmonic distortion and/or phase difference can cause a power factor to be less than 1.0, resulting in greater current demand per useful watt of power.

3.2.1 Model of Raw Supply and Load

The circuit diagram in Figure 3.1 allows examination the raw supply and consumer product in more detail by modeling the raw supply and the load to show their dynamic interaction. The raw supply can be modeled as an ideal[e] voltage source, $V_{RawSupply}$, in series with a resistance, $R_{RawSupply}$. The load, having a total load resistance of R_{Load}, is modeled as two resistors in parallel, R_{Load1} and R_{Load2}, and their corresponding switches, $Switch_1$ and $Switch_2$. The switches and resistors model different functions of the load, which the user controls. V_{Out} is the voltage supplied to the consumer product (i.e., the load) and I_{Out} is the current flowing from the raw supply to the consumer product (i.e., the load).

$$I_{Out} = \frac{V_{RawSupply}}{R_{RawSupply} + R_{Load}} \qquad \textbf{Eq. 3.1}$$

The raw supply voltage and resistance are usually constant, but fluctuations in the mains will change $V_{RawSupply}$ and affect the raw supply output. Equation 1 shows that the current flowing from the raw supply is a function of the load resistance. As the resistance of R_{Load} decreases, I_{Out} will increase.

For example, consider the load in Figure 3.2 as a flat-screen television. The television can be modeled as having two internal functional circuits: video and audio. R_{Load1} and $Switch_1$ represent the screen, while R_{Load2} and $Switch_2$ represent the sound system. In this simplified example, the user can independently turn on the brightness of the screen, closing $Switch_1$, or turn on the volume, closing $Switch_2$. The total resistance of the consumer product, R_{Load}, depends on whether the switches are open or closed, as shown in Table 3.1.

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[e] An ideal voltage source is one that has no internal resistance.

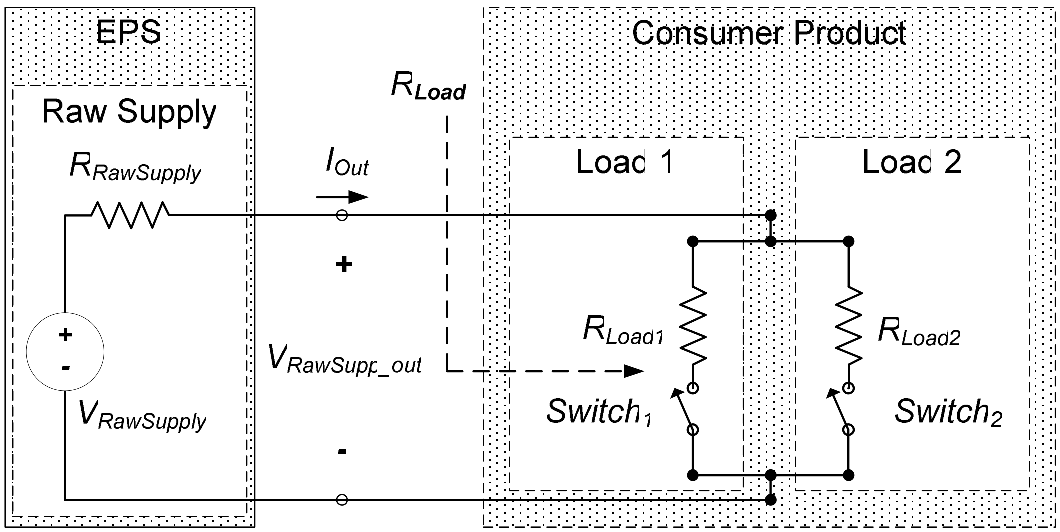

Figure 3.2 Circuit Diagram of a Raw Supply and a Load

Note: Switch1 and Switch2 *are Shown Open.*

Table 3.1 Total Resistance of the Simplified Consumer Product Shown in Figure 3.2

***Switch*₁**	***Switch*₂**	**Total Load Resistance (As a function of switch state)**
Open	Open	$R_{Load} = \infty$
Closed	Open	$R_{Load} = R_{Load1}$
Open	Closed	$R_{Load} = R_{Load2}$
Closed	Closed	$R_{Load} = \dfrac{R_{Load1} \times R_{Load2}}{R_{Load1} + R_{Load2}}$

The state of the switches directly affects R_{Load}. For instance, if the user has the screen on and the sound muted, $Switch_1$ is closed and $Switch_2$ is open. In this case the resistance R_{Load} is simply equal to R_{Load1}, and the current flowing through the circuit, I_{Out1}, is:

$$I_{Out1} = \frac{V_{RawSupply}}{R_{RawSupply} + R_{Load1}} \qquad \textbf{Eq. 3.2}$$

In turn, the output voltage of the raw supply, V_{Out}, is dependent on I_{Out}:

$$V_{Out} = V_{RawSupply} - (R_{RawSupply} \times I_{Out}) \qquad \textbf{Eq. 3.3}$$

Therefore, V_{Out} is a function of I_{Out}, which in turn is dependent on R_{Load}. When the user has both the screen and volume turned on, $Switch_1$ and $Switch_2$ are both closed, and R_{Load} equals R_{Load12}:

$$R_{Load12} = \frac{R_{Load1} \times R_{Load2}}{R_{Load1} + R_{Load}} \qquad \textbf{Eq. 3.4}$$

Since the load resistances are in parallel, R_{Load12} has less resistance than R_{Load1}. Hence, the current I_{Out12} is greater than I_{Out1} and produces a lower output voltage, V_{Out12}:

$$V_{Out12} = V_{RawSupply} - (R_{RawSupply} \times I_{Out12}) \qquad \textbf{Eq. 3.5}$$

When the user makes a seemingly simple change while operating a consumer product, such as muting or turning on the sound, the change affects the entire power supply system. Some devices are tolerant of such changes to V_{Out}; however, other devices, particularly digital electronics, require a stable V_{Out} regardless of a changing R_{Load}. In this example of a flat-screen television, the user might see the effect of a lower V_{Out} as the screen dimming slightly.

Consumers probably would not accept a television that dims when the sound is turned on. In the case of a computer, loads, such as the microprocessor, could fail entirely if V_{Out} changes too much. For both the television and the computer, a raw supply alone clearly cannot meet their voltage demands, in which case the load requires a regulator (as shown in Figure 3.3). Whether or not an EPS is regulated, as well as what type of regulation is used, impacts both its utility and its efficiency.

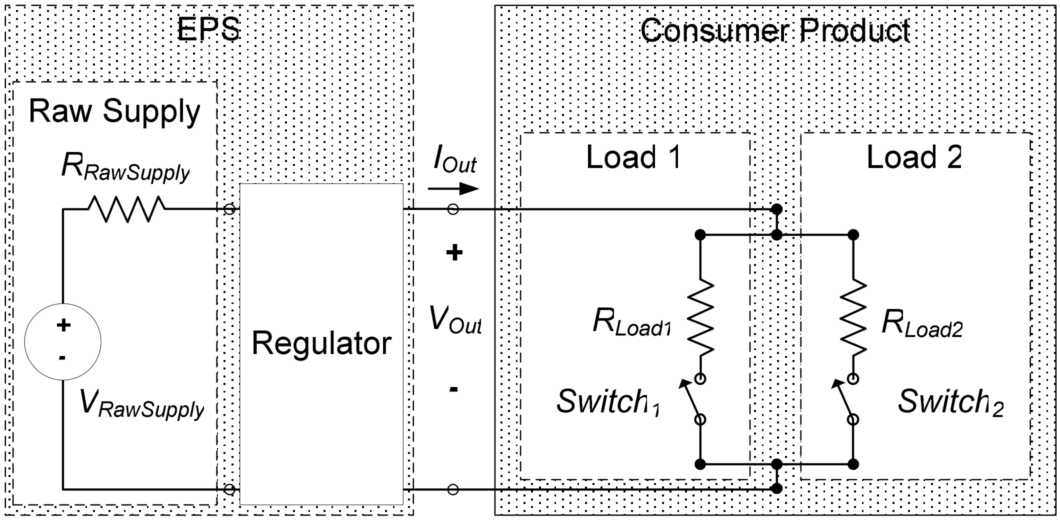

Figure 3.3 Circuit Diagram of a Raw Supply and a Regulator

Note: $Switch_1$ and $Switch_2$ are shown open.

A regulator circuit ensures that after the raw supply converts AC mains power the output voltage applied to the load is relatively stable, regardless of changes in the power consumption of the consumer product.[f] Additionally, the regulator maintains stable V_{OUT}, even for variations in $V_{RawSupply}$ caused by changes in the mains, such as line voltage variations. Section 3.2.2.2 discusses how the regulator provides this functionality, ensuring a stable V_{OUT}. Regulator circuits are located between the raw supply and the load; consequently, they can be housed either in the EPS itself or in the consumer product (see Figure 3.4). Electronically, there is little difference between having the regulator circuit incorporated into the EPS and having it incorporated into the consumer product. Instead, manufacturers decide the location of the regulator based primarily on cost, as well as size, weight, and heat management.

[f] An AC regulator circuit is possible; however, since it is uncommon, it is not examined here.

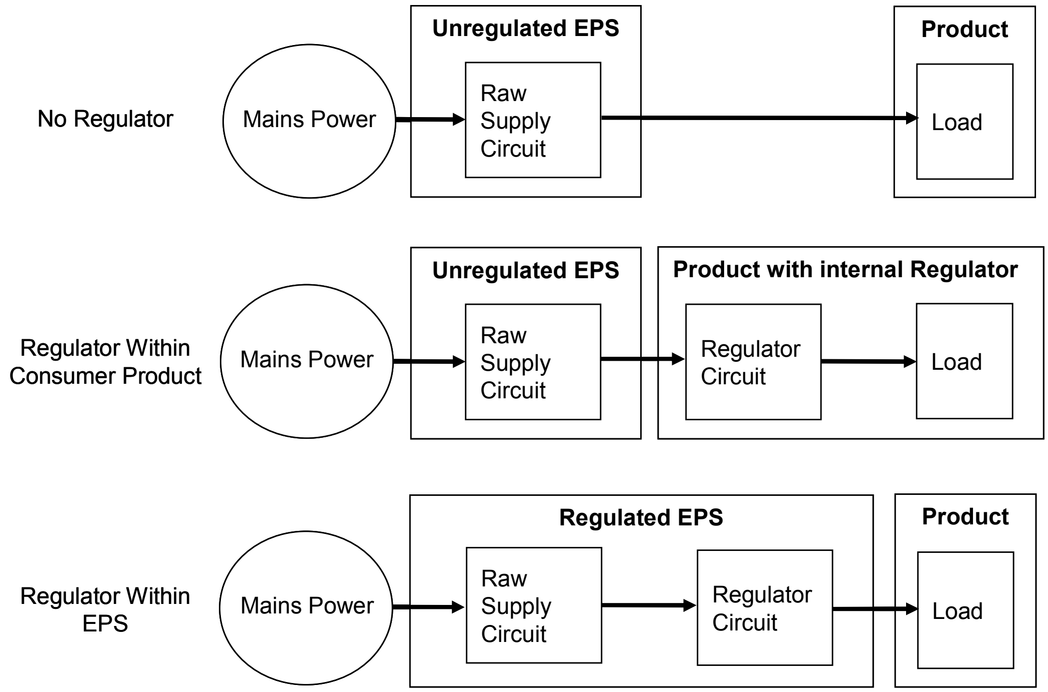

Figure 3.4 Block Diagram Showing Possible Locations for the Regulating Circuit

In general, EPSs are manufactured in two types: regulated and unregulated. Both types include a raw supply circuit to provide voltage isolated from the mains and converted to the required voltage for the consumer product. If a stable output voltage is required, a regulating circuit is added to the system, either bundled with the consumer product or incorporated with the raw supply in the EPS. There are two main types of regulators: linear and switching. A primary difference between the two technologies is that linear regulators operate on isolated DC voltage converted by the raw supply at 60 hertz (Hz) line frequency, whereas switching regulators operate on non-isolated DC voltage at high frequency (20 kilohertz (kHz) or greater). Depending on the regulation technology, the voltage isolation in the EPS occurs within the regulator, instead of within the raw supply, as in the case of a switching regulator.

3.2.2 Technical Analyses of Raw Supply and Regulator Circuit

3.2.2.1 Technical Analysis of a Raw Supply

A line frequency[g] raw supply has three distinct stages (see Figure 3.5): a transformer to isolate and step-down mains voltage, a rectifier to convert AC voltage to DC voltage, and a filter capacitor to smooth the output voltage.

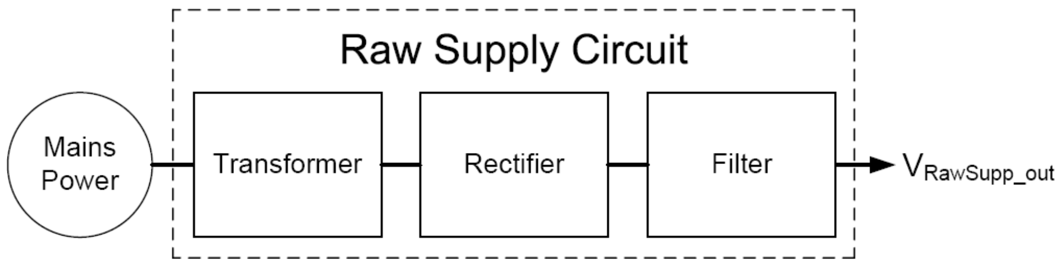

Figure 3.5 Block Diagram of a Line Frequency Raw Supply

One of the fundamental components of the EPS, the transformer, consists of two windings of wire around a magnetic core. An AC voltage on one winding, the primary, induces a magnetic field in the core, which, in turn, induces a voltage in the secondary winding (see Figure 3.6). The induced voltage depends on the relative number of turns of wire between the primary and the secondary. In the raw supply, the windings of the transformer are wound so that the voltage generated in the secondary is at the design voltage for the consumer product when mains voltage is applied to the primary. Further, since the primary and secondary windings are two separate wires, the transformer also fulfills the UL-listing requirement of electrically isolating the consumer product from the mains. In the line frequency raw supply, the transformer is the component that consumes the most energy. The key factors that determine the losses of the transformer are core size, core materials, number of windings, wire material, and

[g] Line frequency is 60 Hz, the frequency of mains AC voltage

wire gauge. In an AC-AC EPS, the raw supply output is that of the transformer. However, most EPSs are AC-DC and require additional components for rectifying and filtering the output voltage. For AC-DC EPS that have a low output voltage, below approximately 10 V, the power consumed by the diodes also becomes significant.

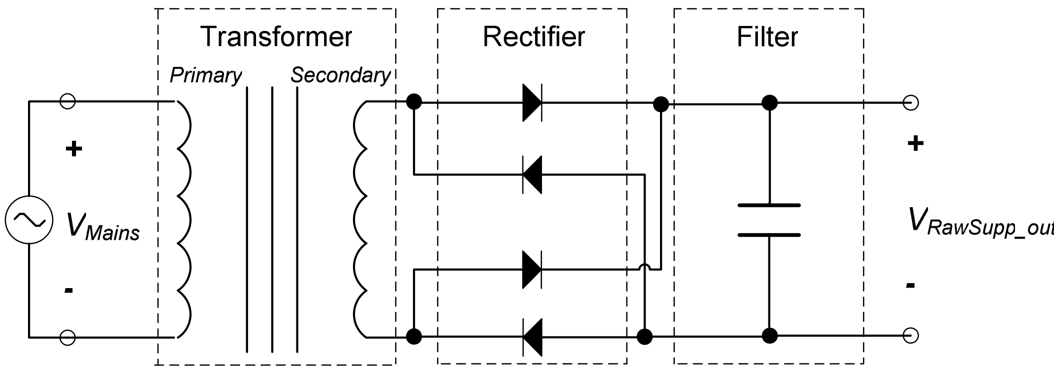

Figure 3.6 Diagram of a Line-Frequency Raw Supply Circuit

In an AC-DC raw supply, a diode bridge takes the AC voltage from the secondary winding of the transformer and rectifies it to DC (see Figure 3.6). In this step, the sinusoidal AC voltage that rises and falls equally between positive and negative voltage is full-wave rectified. Next, a capacitor smoothes the rectified DC voltage, producing an output voltage that is almost flat but still has a slight ripple indicative of its AC origins.

To summarize, the raw supply, consisting of a transformer, rectifier, and filter capacitor, is directly responsive to the load. The transformer is the component which most strongly impacts the raw supply's efficiency. A change in the mains power or the resistance of the load directly affects the output voltage of the raw supply. If required, a regulator circuit follows the raw supply circuit, housed either in the EPS or in the device before the load. In the next section, this regulator circuit is discussed in more detail.

3.2.2.2 Technical Analysis of a Regulator Circuit

Regulator circuits in EPSs ensure a stable output voltage to consumer products, regardless of changes in the mains or the load. There are two main types of regulator circuits: linear and switching. Linear regulators use feedback to provide a steady output by dissipating extra power as heat. Feedback also is used in switching-regulated external power supplies that send high-frequency pulses of power from the raw supply to an energy transfer system, which provides constant output to the load. Of the two regulator technologies, linear regulators are simpler, bulkier, cheaper, and generally less efficient at higher power levels than switching regulators. Switching regulators, although more complicated and costly, provide a good alternative when portability or over-heating is a concern, such as when an EPS is used with a mobile phone charger or a high-power flat-panel television.

Technical Analysis of a Linear Regulator Circuit. Linear regulators have two key elements; a sensor and a pass device, that work together to produce a stable output voltage (see Figure 3.7). The pass device controls the output of the regulator by adjusting the output to achieve a stable output voltage. To determine those adjustments, the sensor element continuously compares the output voltage to a reference voltage. Whenever there is a difference between the two voltages, the sensor directs the pass device to adjust the output so as to reduce that difference. This continuous adjustment allows the regulator to yield a constant output voltage as the load resistance or mains voltage varies. The output voltage of the linear regulator circuit is what the user sees as the output voltage of the EPS.

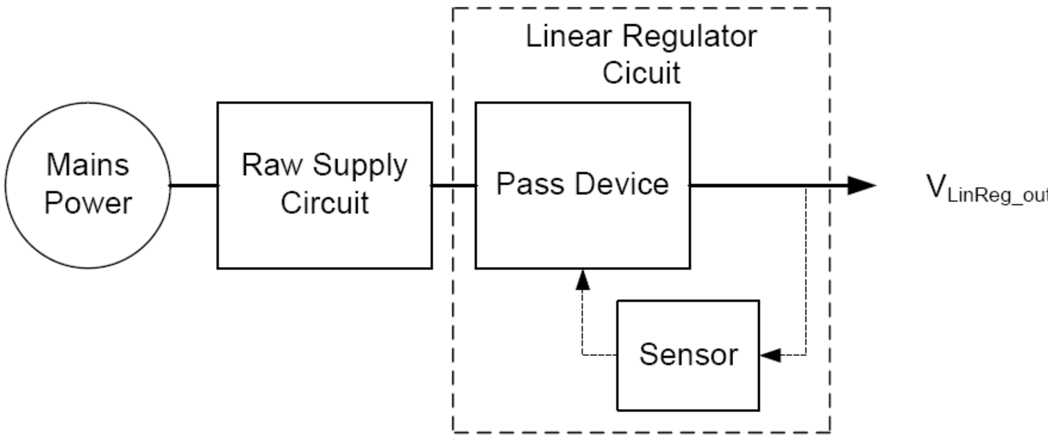

Figure 3.7 Block Diagram of a Linear Regulator

For the purposes of this technology assessment, Figure 3.8 shows a “low-dropout” linear regulator, one of the more common types of linear regulators. However many other linear regulation designs also exist. The fundamental function of a linear regulator is to dissipate excess power in order to provide constant voltage to the load. To do this, the pass device changes its voltage drop while a constant current passes through it to the load. To determine that voltage drop, an operational amplifier (commonly referred to as an “op-amp”) compares the output voltage against a reference voltage. Based on those two signals, the op-amp controls the voltage drop across the pass device. That voltage drop determines the output voltage but also dissipates energy. The energy dissipated by the pass device is the main source of energy consumption in the linear regulator, and hence the main source of inefficiency and heat generation. Together, the sensor and the pass device adjust the output of the regulator to produce a relatively stable output voltage, which is what the load receives as the output voltage of the EPS.

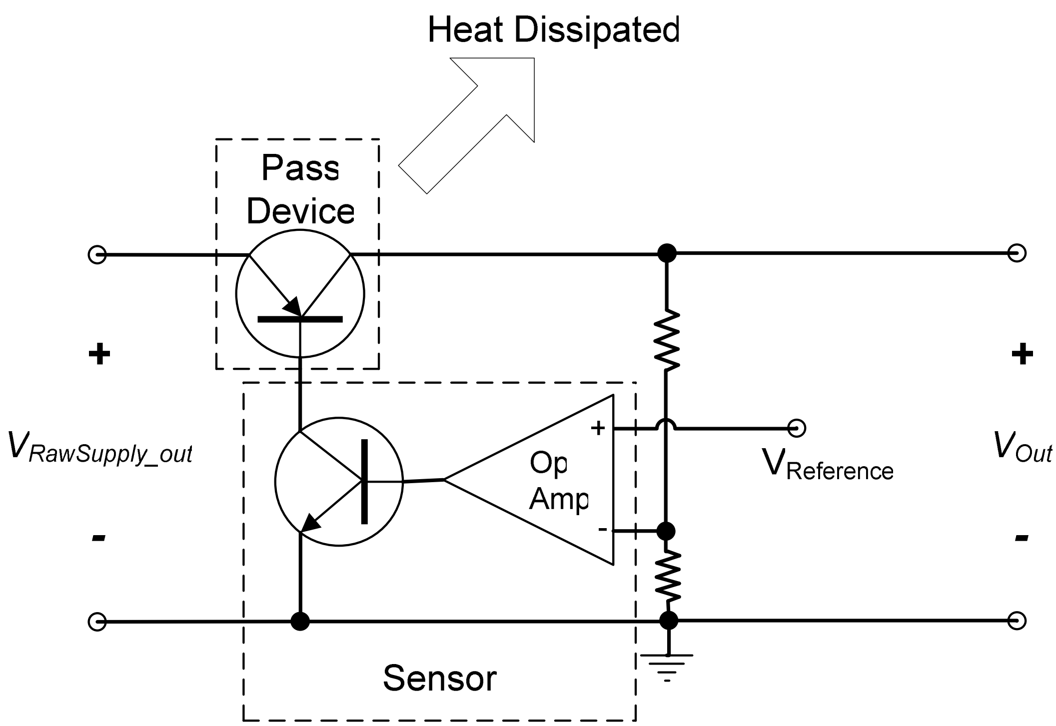

Figure 3.8 Simplified Circuit Diagram of a Linear Regulator

The efficiency of the linear regulator, η_{LinReg}, is:

$$\eta_{LinReg} = \frac{P_{LinReg\_out}}{P_{LinReg\_in}} = \frac{V_{LinReg\_out} I_{LinReg\_out}}{V_{LinReg\_in} I_{LinReg\_in}} \quad \textbf{Eq. 3.6}$$

Where P_{LinReg_out} is the power out of the linear regulator, P_{LinReg_in} is the power into the linear regulator, V_{LinReg_out} is the voltage out of the linear regulator, V_{LinReg_in} is the voltage into the linear regulator, I_{LinReg_out} is the current out of the linear regulator, and I_{LinReg_in} is the current into the linear regulator. Since the linear regulator attaches to the raw supply, V_{LinReg_in} is equal to $V_{RawSupp\_out}$, the output voltage of the raw supply.

Since the input current flows directly to the output via the pass device, with other currents being negligible, $I_{LinReg\_out} \approx I_{LinReg\_in}$. Therefore, the efficiency of the linear regulator alone is approximately:

$$\eta_{LinReg} \approx \frac{V_{LinReg\_out}}{V_{LinReg\_in}}$$ **Eq. 3.7**

The total efficiency of an EPS with a linear regulator depends on the efficiency of both the linear regulator circuit and the raw supply. Depending on the load conditions, η_{LinReg} generally ranges from 0.6 to 0.8, meaning the linear regulator is about 60 to 80 percent efficient. The efficiency of raw supply, η_{RawSup}, also varies with load, generally from 0.7 to 0.9. The raw supply and linear regulator each are most efficient at different load conditions. Multiplied, η_{LinReg} and $\eta_{RawSupp}$ yield the total efficiency of an EPS with a linear regulator, η_{Lin_EPS}, which is generally about 50 percent, but decreases rapidly for EPS below 10 W:

$$\eta_{Lin\_EPS} = \eta_{RawSupp} * \eta_{LinReg}$$ **Eq. 3.8**

For an EPS consisting of a raw supply and a linear regulator, mains voltage at line frequency (60 Hz) is directly applied to the transformer. If the power applied to the transformer had similar voltage and current characteristics but a higher frequency, the transformer could be smaller and lighter. Those benefits are part of the motivation for choosing switching regulators (discussed in the next section), which, unlike their linear counterparts, have transformers that operate at high frequency (greater than 20 kHz).

Technical Analysis of a Switching Regulator Circuit. Switching regulators achieve a stable output voltage using a different and more complex scheme than linear regulators. As a result, switching regulators are generally smaller and lighter than linear regulators. In addition, switching regulators are more efficient because they only take power from the mains as necessary and they store and return energy with low loss. To do this, switching regulators employ a four-stage high-frequency power conversion process that takes power from a raw supply. In a switching EPS, the raw supply circuit is still between the mains and the regulator circuit, but it does not contain a transformer and performs only AC to DC conversion and voltage smoothing. The high-voltage DC enters the switching regulator, which lowers the voltage and isolates the consumer product from mains power in addition to stabilizing the output voltage.

The switching regulator consists of four stages: a chopper stage, an energy transfer stage, a control stage, and a feedback isolation stage (see Figure 3.9). First, the chopper converts the DC voltage from the raw supply to a high-frequency rectangular-wave AC voltage. The energy transfer stage then takes energy from the AC voltage produced by the chopper and uses it to provide the output voltage for the switching regulator—the same voltage the user sees as the output of the EPS. The energy transfer stage also serves to isolate the user from the mains. The level of the output voltage is fed back, via an isolation stage, to the control stage, which tracks the output voltage and adjusts the chopper to supply the proper amount of energy.

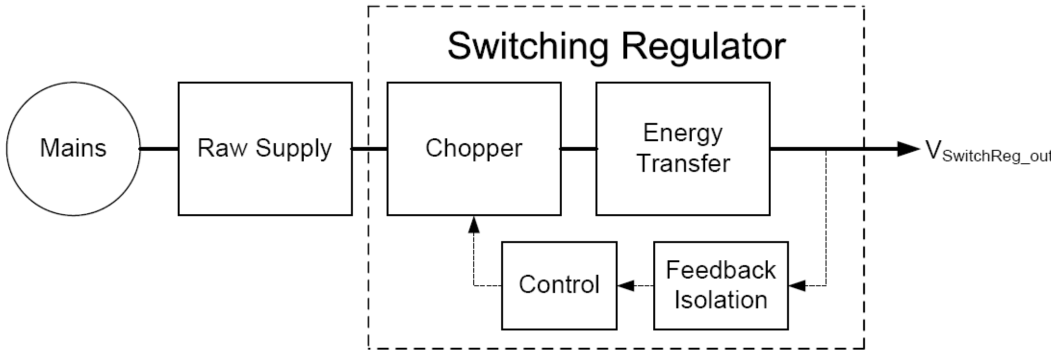

Figure 3.9 Block Diagram of a Switching Regulator

The switching regulator usually consists of an integrated circuit and discrete components. The circuit diagram in Figure 3.10 is for a “flyback” switching regulator, one of the more common types; however, many other switching regulator designs also exist. The chopper stage uses a transistor, which switches on and off at high frequency to convert the DC signal from the raw supply to an AC signal for the energy transfer stage. The transistor is driven by the control stage and different amounts of energy are transferred based on its switching frequency and duty cycle. The switching frequency is in the kilohertz range, with lower frequencies having lower switching losses. Typically, the lowest frequency, hence having the lowest losses, is 20 kHz, so as to be above the audible range of human hearing. The chopper acts as a switch that lets the EPS take power from the mains only when it is closed. While the switch is open, only a small leakage current flows through the raw supply. The switching function provided by the chopper is integral to the efficiency of the overall EPS.

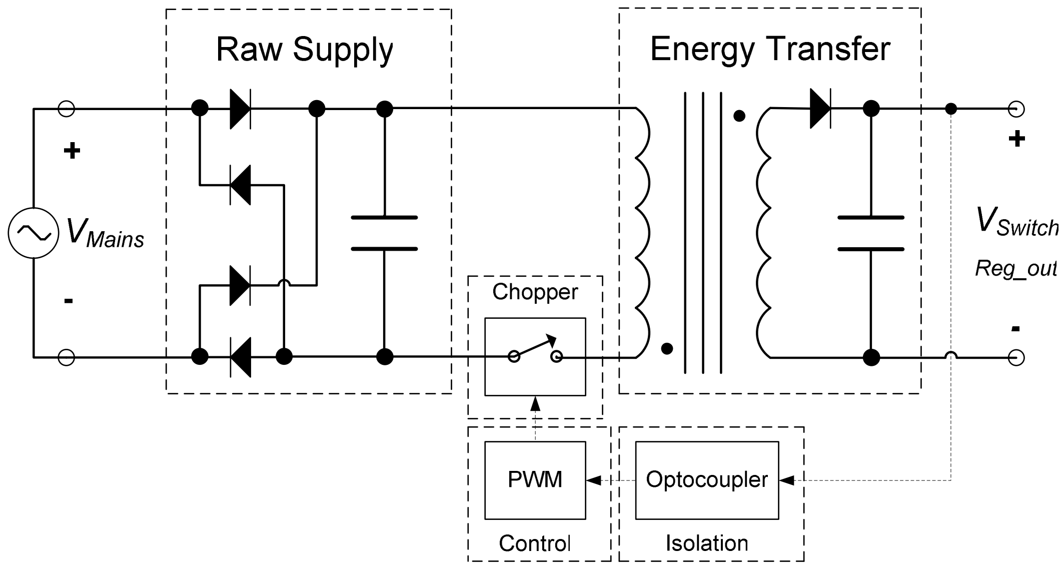

Figure 3.10 Simplified Circuit Diagram of a "Flyback" Switching Regulator

The energy transfer stage consists of a choke, a capacitor, and a diode. The choke is very similar to a transformer and has the same symbol in the circuit diagram. One difference is that a transformer is designed to pass energy from one winding to another with minimal energy storage, while a choke is designed to store and release energy. Another difference is that in the line frequency transformer, the phasing of the windings is not important, while the phasing of the choke winding in the flyback switching regulator is critically important and is represented in Figure 3.10 by dots on the choke. A two-winding choke can be used to electrically isolate, as well as store and release energy.

When the chopper switch is closed, the primary winding of the choke takes energy from the chopper and stores the energy in the choke. When the chopper switch opens, the secondary winding transfers that energy through the diode to the capacitor and provides the output for the switching regulator, electrically isolating the load from the mains. Since the choke operates at a high frequency, it benefits from the associated decreases in size and weight. The energy transfer scheme of the switching regulator is more efficient than a linear regulator, in part because the choke stores and returns energy with relatively low losses.

The isolation stage typically uses an optocoupler that consists of a light source and a photosensitive detector. By converting the electrical feedback signal to an optical one, the optocoupler maintains the load electrically isolated from the mains. The detector converts the optical signal back to an electrical signal that it provides to the controller.

Generally, the controller is an integrated circuit that drives the chopper with a high-frequency pulse-width-modulated (PWM) rectangular wave. The controller monitors the EPS output voltage and adjusts the pulse width to increase or decrease the amount of energy transferred by the chopper. If the output voltage dips, the controller will increase the duty cycle, thus increasing the energy passed by the energy transfer stage and increasing the output voltage. Conversely, if the output voltage rises, the controller will decrease the duty cycle or possibly skip cycles. This cycle-skipping feature is especially useful when there is no load attached, since the EPS will only take from the mains the small amount of power it needs to power itself.

The major difference between the two regulating schemes, in terms of energy efficiency, is that the switching regulator can modulate the power drawn from the raw supply, taking only what the load needs. This is opposed to the linear regulator, which takes more power than necessary and dissipates the excess power as heat. However, the controlling circuitry used by the switching regulator consumes more power than the linear regulator. Thus at output power levels greater than 10 W switching regulation is more efficient, but at output power levels lower than 10 W the range of efficiencies for both types of regulation is similar.

Both linear-regulated and switching-regulated EPS employ regulating circuits to achieve a stable output voltage. However, voltage is not the only output variable that can be regulated. Current regulation, as discussed in the following section, is a fundamental consideration in BC design.

3.3 BATTERY CHARGERS

Although BCs and EPSs are both power converters, BCs are technically different from EPSs in many ways. First, BCs are current sources custom-designed for use with specific batteries, whereas EPSs are interchangeable voltage sources capable of powering different types of loads. Second, BCs operate in maintenance mode whereas EPSs do not. Third, the EPS's load can be treated as a variable resistance with a linear relationship between current and voltage. Conversely, the rechargeable battery model is an electrochemical process with a complex relationship between current and voltage. Fourth, batteries are generally more sensitive to heat than loads powered by EPS. As a result of these differences in operation, battery chargers are not interchangeable and should be evaluated with their corresponding batteries as a battery charging system, as shown in Figure 3.11. These critical differences between BCs and EPSs are summarized in Table 3.2.

Table 3.2 Differences between BC and EPS

Battery Chargers	External Power Supplies
Key Differences:	

• Primarily a current source
• 3 modes of operation
  o Active mode
  o Maintenance mode
  o No-load (standby) mode
• Battery model is electro-chemical
• Excessive battery heating degrades battery life and poses a safety hazard
• BC are designed for specific batteries and are not interchangeable
	• Primarily a voltage source
	• 2 modes of operation
	  o Active mode
	  o No-load mode
	• Load model is a variable resistance
	• Heat does not necessarily affect EPS or load life
	• EPS are designed for a certain output, and are interchangeable

Conclusions:	
Battery and BC should be evaluated together	EPSs can be evaluated apart from their loads

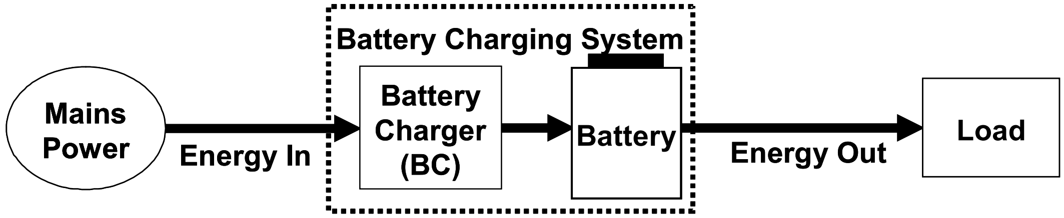

Figure 3.11 A battery and BC as part of a battery charging system

In some cases, an EPS delivers power to a consumer product that, along with other functions, has an embedded battery and battery charging circuit, shown in Figure 3.12. In this case, the external power supply provides power to all of the functions of the consumer product, including the battery charger.

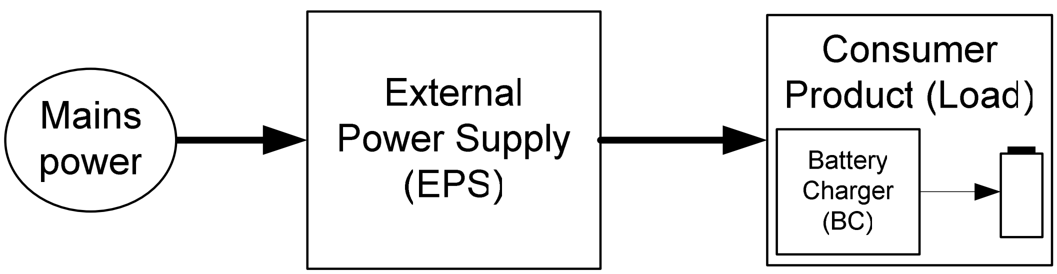

Figure 3.12 An EPS-powered consumer product with an internal BC and battery

In active mode, the electrical characteristics of a rechargeable battery change during the charging process and thus batteries require monitoring to prevent overcharging and/or overheating. Therefore, the circuit model for the battery is a device with certain electro-chemical characteristics, as shown in Figure 3.13, as opposed to a simple resistor model which represents an EPS load. In the case of an ideal EPS, the output voltage is constant regardless of the output current. Ideal battery chargers output a constant current while the charge state of the battery determines the output voltage. Many BC's have a charging regulator which controls output current as opposed to voltage regulators which control output voltage in EPS.

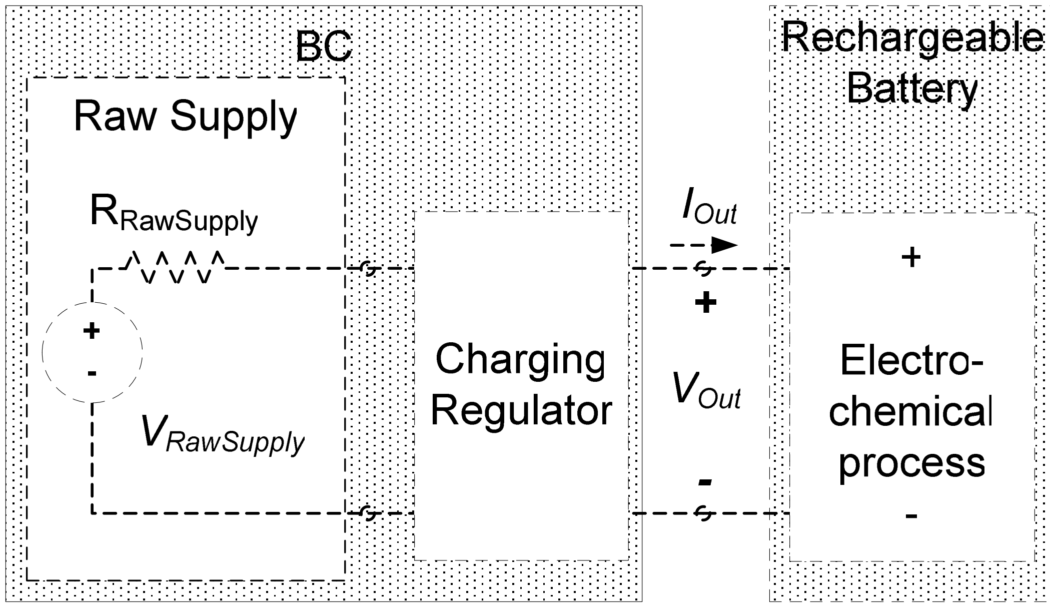

Figure 3.13 Circuit diagram of a BC

The current output of a BC is most critical when the battery is fully charged and when the battery is empty. When the battery is empty of charge it has a very small voltage. Consequently the BC could output high current into an empty battery, potentially causing battery damage and posing a safety hazard due to heat generation. Therefore it is crucial that BC limit charging current until the battery voltage increases.

While charging a battery, the BC is in active mode; once the battery is at full charge, the BC switches into maintenance mode. In maintenance mode the BC prevents the battery from discharging by applying maintenance current. If the maintenance current is too high, the battery can be damaged due to excess heat generation or unwanted electro-chemical reactions. If the maintenance current is too low, the battery can self discharge resulting in the consumer product not meeting performance requirements.

The type of the maintenance current depends on battery type. Lithium-ion (Li-Ion) batteries do not significantly self-discharge but do pose a serious safety hazard if over-charged.

Consequently, Li-Ion BCs stop charging once the battery is full and require zero maintenance current. Conversely, Nickel-Cadmium (NiCd) batteries significantly self-discharge and are tolerant of overcharging. Hence, once the NiCd battery is fully charged, NiCd BCs continue to provide maintenance current to keep the battery fully charged.

BCs generally have two charger types: continuous charging (sometimes referred to as slow charging) and terminating charging (sometimes referred to as fast charging). Continuous-charging BCs are more commonly found in consumer products that compete on low first-cost and/or products that operate infrequently and spend most of their life in maintenance mode. An example of such a product is a cordless hand-vacuum, which spends most of its life in a charging-base awaiting use. Continuous BCs provide current to the battery using the same circuit regardless of battery state and usually only monitor the battery for safety purposes, not for adjustments to the charging current. The charging current of a continuous BC is low which results in a slow charge. For infrequently used consumer products slow charging does not affect usability, as in the case of a portable hand-vacuum, since time between uses is much greater than charging time. The major benefit of continuous BCs is that they require fewer parts than terminating BCs and, hence, are simpler and cheaper. Although continuous BC have fewer parts to consume energy, they still might consume more energy than necessary. Since the same circuit charges the battery in active mode as in maintenance mode, a continuous BC may output, and input, more energy than necessary in maintenance mode.

Terminating BCs offer additional functionality, but at an increase in complexity and cost. Terminating BCs recharge a battery more quickly than continuous BCs because they provide a high-current charge while the battery can safely accept it (during active mode). For example, a cordless power-drill with a rapid-charge BC uses a high current to quickly charge the battery, often in an hour. Once the battery is fully charged, the BC maintains the battery at full charge with a lower current. To determine when to charge at high current, terminating BCs monitor inputs such as battery voltage, rate of change of battery voltage, battery temperature, rate of change of battery temperature, charging time, and charging current. These inputs direct a charging regulator in the BC to adjust output current.

In terminating BCs the two primary sources of energy consumption (and opportunities for energy savings) in BCs are transformers and battery monitoring circuits. If the terminating BC uses a transformer to step-down voltage, then the transformer must be large enough to handle the maximum output power of the BC in active mode. Consequently, since core losses are fixed, the transformer has the same core losses in maintenance mode as it does in active mode. For the terminating BC, a potentially significant source of energy consumption is the power consumed by the circuits that monitor battery state to adjust BC input and output power.

In terms of maximizing energy efficiency and minimizing energy consumption, neither continuous BCs nor terminating BCs are inherently better. The factors determining overall BC energy consumption are the energy consumption of different parts of the BC, the output power of the BC in different battery states, and consumer usage patterns. Terminating BCs and continuous BCs consume energy in different ways. Depending on the state of the battery, terminating chargers adjust their input and output power. This adjustment allows terminating BCs to minimize consumption when delivering little power to the battery. However, this ability comes at a cost: the electronics necessary to monitor the battery and adjust power levels consume energy and increase the cost of the BC. Depending on the design, the energy consumption of the monitoring electronics adjusting the output can exceed the energy savings gained by adjusting the output power.

As opposed to terminating BCs, continuous BCs do not adjust input and output power based on the state of the battery. Thus, continuous BC does not have the ability to reduce power input when delivering little or no power to a battery. However, that same lack of battery-monitoring components reduces their cost as well as power consumption.

Typically, BCs are in higher-power active mode for only a brief portion of each charge cycle, spending the majority of their time in lower-power maintenance mode. Additionally, many chargers consume power in no-load mode when the battery is removed and all input energy is wasted. Consequently, an important step to improve the overall energy efficiency of BC is to reduce the amount of power consumed in maintenance and no-load modes.

3.4 EFFICIENCY IMPROVEMENT OPPORTUNITIES

When BC and EPS convert power, the amount of power taken from mains depends on the power consumed by the converter and the power demanded by the rechargeable battery or load. These power demands also determine the three different operational modes: active mode, maintenance mode, and no-load mode. BC and EPS have different efficiencies in each mode because of their different associated power requirements. The efficiencies of the modes, together with how users operate the consumer product with the BC, determine the energy-savings opportunities.

Issue 35: *DOE invites comment on power consumption and consumer use patterns of BCs and EPSs.*

3.4.1 Power Consumption in Different Modes

Active mode is the operational mode when the power converter performs its intended function: powering a load or recharging a battery. When EPSs and BCs are in active mode, they occasionally operate at maximum rated output power, but usually operate at lower power. A key difference between BCs and EPSs is how consumers typically use them: EPSs tend to spend time in active mode powering a load, whereas BCs spend relatively little time in active mode charging a battery. Instead, BC spend significant amounts of time in maintenance mode preserving the battery at full charge. Based on these usage patterns, there are energy savings opportunities for EPS in active mode. For BC, while the active mode could be more efficient, it is only a part of the overall opportunity for increased energy savings.

Maintenance mode, which applies only to BC, offers a promising energy savings opportunity, since BC spend much of their operational time maintaining a battery at full charge. Since little power is required to maintain the full charge, BC may consume more power than might otherwise be necessary.

Another opportunity for energy savings is no-load mode. If a BC or EPS is connected to mains, but disconnected from a load or battery, it still consumes energy while delivering no energy to a load or battery. Thus, minimizing no-load energy consumption is a step towards reducing the overall energy consumption of the BC or EPS.

3.4.2 External Power Supply Power Consumption

The purpose of the EPS is to deliver power to the load, but the EPS also consumes some power itself. Active mode efficiency of the EPS is defined as delivered power divided by input power. Hence, decreasing the power consumed by the EPS will increase its efficiency. In active mode, EPS power consumption increases with power output. In no-load mode, when an EPS does not deliver output power, it still consumes power.

To present energy savings opportunities clearly in this section, DOE selected two common types of EPS: unregulated line frequency (60 Hz) and switching regulated high frequency (greater than 20 kHz). The two types of EPSS discussed are considered for the case of high efficiency and low efficiency. Figure 3.14 compares the power delivered to the power consumed by the four EPS types in active mode at 25 percent and 100 percent of maximum rated output, as well as in no-load mode.[h] DOE presents data for a 5-watt and 50-watt EPS, which are two common power ratings. These EPS types, and their relative performance, are derived from an EPA database of 190 EPS models that were tested for the purposes of developing the ENERGY STAR standard.[i]

Issue 36: *DOE invites comment on the quantities and different types of EPSs in the market, especially unregulated line frequency EPSs and switching regulated EPSs.*

[h]For the line-frequency EPSs, assumptions in the high-efficiency model are that copper losses are half those in the baseline model and transformer no-load losses are reduced. For the switching EPS, assumptions for the high-efficiency EPSs are that it has reduced no-load losses, as well as lower switching and conduction losses. Diode losses are assumed to be the same in both models.

[i]The EPA used "Test Method for Calculating the Energy Efficiency of Single-Voltage External Ac-Dc and Ac-Ac Power Supplies," 2004, which is the same test procedure proposed by DOE on July 25, 2006. 71 FR 42178.

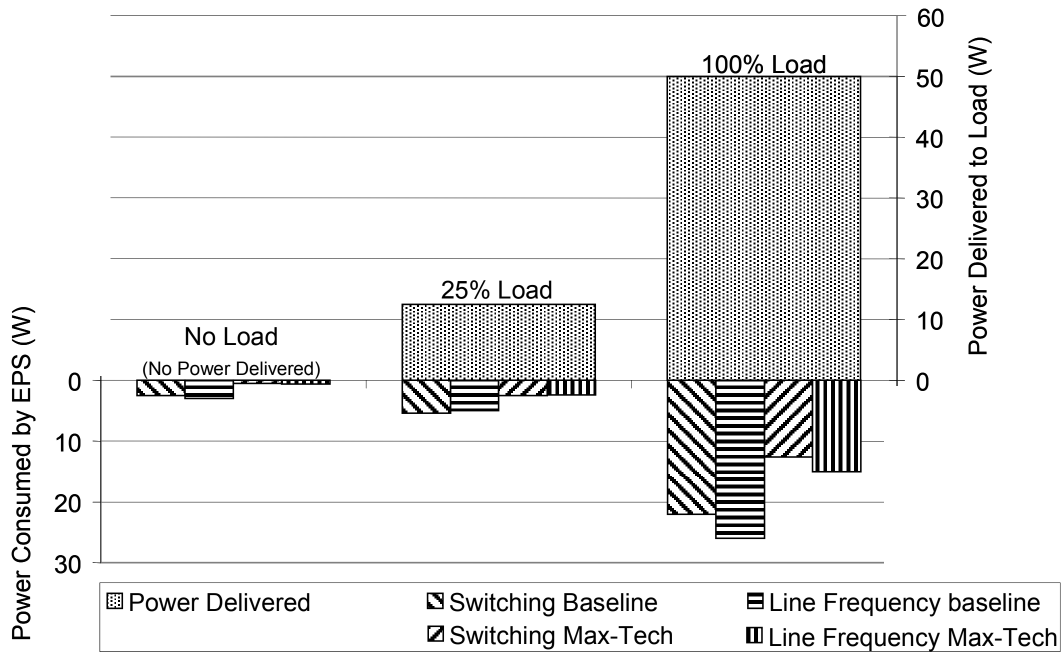

Figure 3.14 Energy Delivered and Consumed by Four 50-Watt External Power Supply Types

The four EPSs shown in Figure 3.14 have a 12 V output and a maximum rated output power of 50 W, which are roughly representative of possible notebook computer EPS. In this case, smaller amounts of power consumed by an EPS are indicative of a more efficient power converter. Looking at the case of 100 percent load in the right column of Figure 3.14, the least efficient EPS shown is the low-efficiency line-frequency (60 Hz) unregulated EPS, which consumes approximately 25 W as it delivers 50 W to the load. This represents an efficiency of approximately 67 percent (50/(50+25)). The most efficient EPS shown in the case of 100 percent load is the high-efficiency switching-regulated EPS, which consumes just 12 W—or about half the power consumption of the least efficient model. The efficiency of the high-efficiency switching-regulated EPS is approximately 81 percent (50/(50+12)). A similar plot, shown in Figure 3.15, considers the case of four 5 W EPS types, which are roughly representative of possible power converters for a mobile phone.

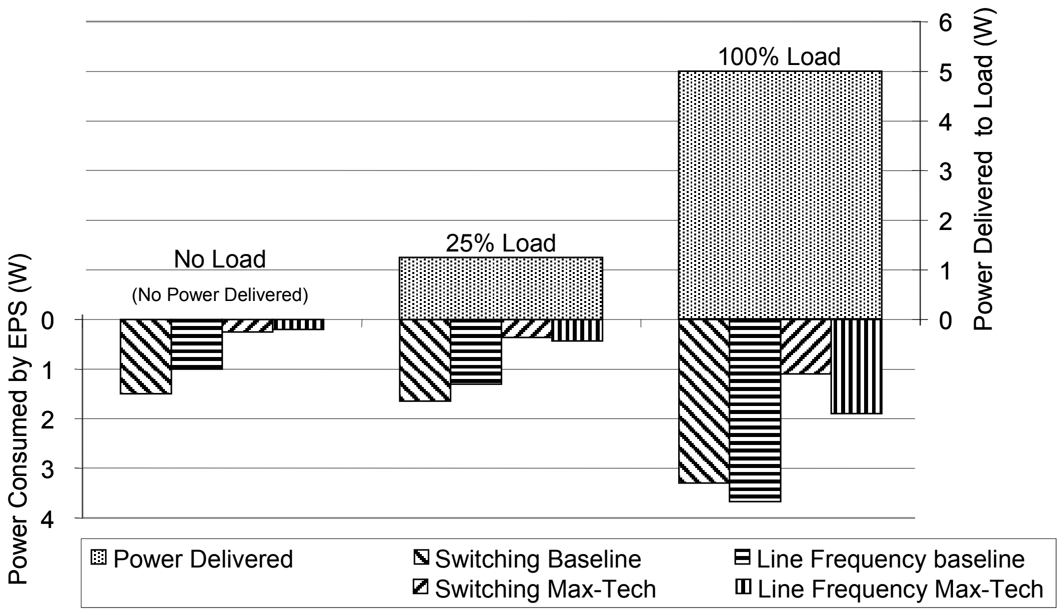

Figure 3.15 Energy Delivered and Consumed by Four 5-Watt EPS Types

The greatest opportunity for energy savings, in percentage terms, for both a 50 W and a 5 W EPS, occurs in the no-load mode. For the 50 W EPS, the decrease in power consumption is from 2.5 W to 0.5 W, a five-fold decrease. This proportional decrease also is observed with the 5 W EPS, where the no-load mode power ranges from 1 W for the low-efficiency model to 0.2 W for the high-efficiency.

To convert these differences in wattage consumption to kilowatt-hours per year, DOE estimated what the electricity consumption would be for the low- and high-efficiency models of the 5 W switching EPS, assuming it supplies a mobile phone charger.[j] This calculation found that the low-efficiency switching EPS would consume approximately 13.5 kWh/year compared

[j] DOE's preliminary input assumptions for the calculation of mobile phone EPS use: the EPS was unplugged (no-load mode) during the day (16 hours) and used overnight for 1 hour at 100 percent load and 7 hours at 25 percent load. Additionally, the EPS was assumed to be used 4.5 times per week for 51 weeks each year.

with an estimated 2.5 kWh/year for the high-efficiency model. In dollar terms, that converts to $1.21 of electricity for the low-efficiency EPS and $0.23 for the high-efficiency model.[l] Thus, there would be approximately $0.98 of annual operating cost savings between the two designs.

DOE performed a similar calculation for a 50 W power supply, assuming it was operating a notebook computer EPS.[k] This calculation found that the low-efficiency model consumed 60 kWh/year compared with approximately 29 kWh/year for the high-efficiency model. In dollar terms, that converts to $5.41 of electricity for the low-efficiency EPS and $2.59 for the high-efficiency EPS.[l] Thus, there would be approximately $2.82 of annual operating cost savings when comparing the two designs.

3.4.3 Battery Charger Power Consumption Improvements

Typically, the efficiency of a system is a simple ratio of energy output to energy input: $Efficiency = \frac{Energy_{out}}{Energy_{in}}$. In that case, system efficiency improves by reducing energy consumption: $Energy_{consumed} = Energy_{in} - Energy_{out}$.

In the case of BC, the system consists of the BC and battery. The energy output from the system is the energy delivered by the battery to the consumer product. The energy input to the system is the active-mode energy used to refill the battery plus, if necessary, the maintenance-mode energy used to preserve the battery at full charge.

[k] DOE's preliminary input assumptions for the calculation of a notebook computer EPS use: it is a residential computer, used only for leisure and not for business purposes; it is used 6 hours from Monday through Friday, and 3.5 hours on Saturday and Sunday, for a total of 9.5 hours each week. It is assumed that the computer is connected to the EPS during half of its weekly operating time (9.5 hours), and 86% of its non-operating time (158.5 hours).
[l] The assumption of $0.0897/kWh is based on the EIA's 2004 average retail price of electricity to residential consumers.

Different from most systems, it is necessary for BC to operate in maintenance mode where the system consumes energy that does not contribute to the output energy. Further, maintenance mode duration varies for different consumer products as well as for consumer's usage pattern. Therefore, battery charging systems are evaluated in terms of energy consumption and energy output rather than an efficiency metric.

While developing the ENERGY STAR program requirements for BCs, EPA conducted a study which determined that BCs consume significant amounts of energy in maintenance mode, and in no-load mode. The findings from this study are shown in Figure 3.16 and Figure 3.17, which show energy consumption in a continuous and terminating BC, respectively. Losses in active mode are also substantial in continuous BC, albeit less so for terminating BC. Both terminating and continuous BC consume a significant percentage of their total energy input in maintenance mode and no-load mode. Thus, in developing its program requirements, EPA considered BC energy consumption in all three modes of operation.

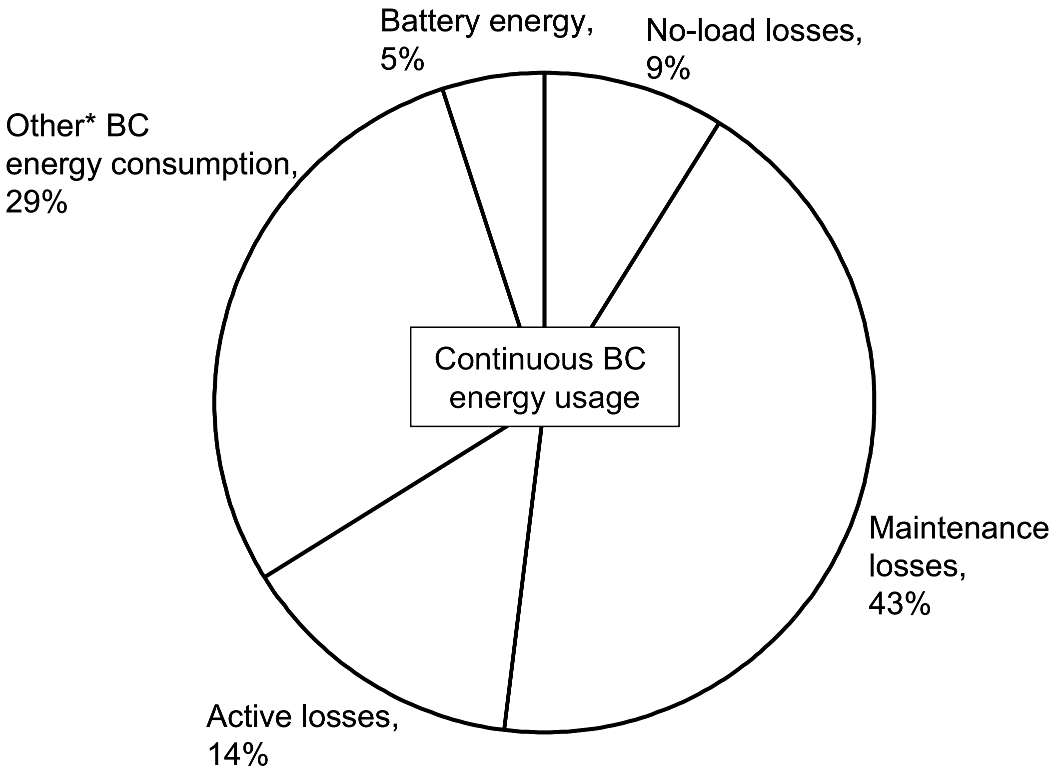

Figure 3.16 Energy usage in a continuous charge rate BC

**Other BC energy consumption represents the sum of the energy input, cell equalization energy, required battery maintenance energy, and added required charge.*

Source: U.S. Environmental Protection Agency and The Cadmus Group.

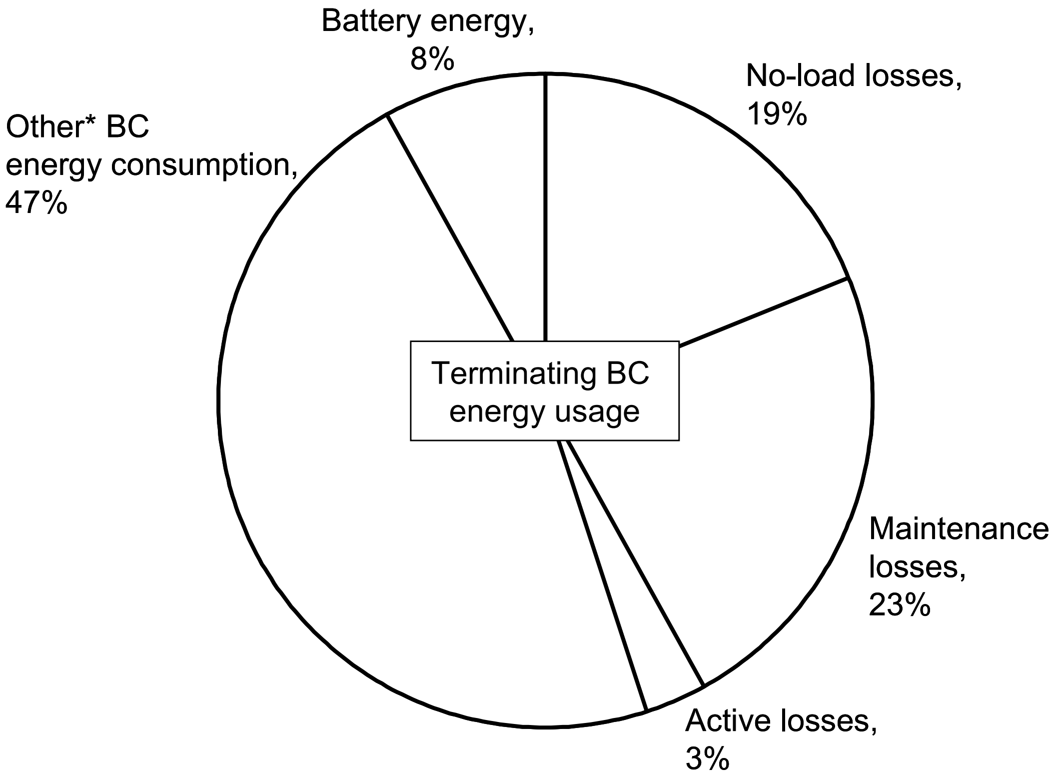

Figure 3.17 Energy usage in a terminating charge rate BC

**Other BC energy consumption represents the sum of the energy input, cell equalization energy, required battery maintenance energy, and added required charge.*

Source: U.S. Environmental Protection Agency and The Cadmus Group.

In Figure 3.18, the non-active energy and total energy consumed are plotted against battery voltage for 26 battery charging systems.[m] This study was the basis of EPA's decision to evaluate BC based on non-active energy consumption. The plot shows proposed ENERGY STAR levels for both non-active and total energy. EPA came to the conclusion that most products that qualified as ENERGY STAR when evaluated for total energy were the same products that qualified for ENERGY STAR when evaluated for non-active energy. Therefore, to minimize the testing burden and simplify the test procedure, the ENERGY STAR test procedure only evaluates BC energy consumption in maintenance mode and no-load. ENERGY STAR recognizes BCs that are more efficient in active mode based on the correlation shown in Figure

[m] ENERGY STAR Battery Charger Stakeholder Meeting Presentation, pp. 60.

3.18; however, ENERGY STAR evaluates BCs for non-active energy at the non-active proposed level.

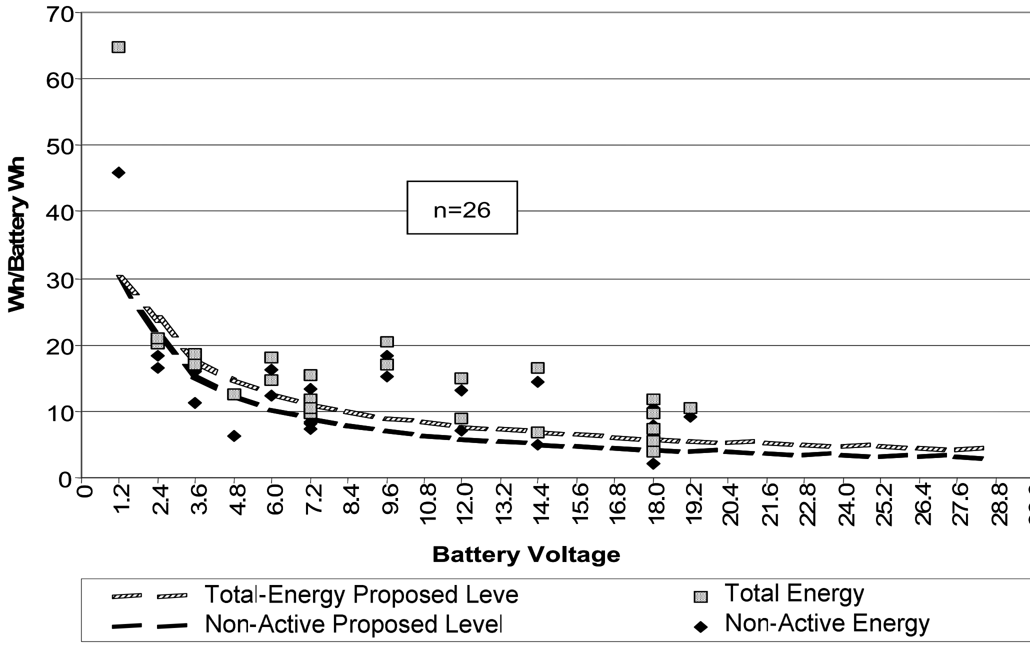

Figure 3.18 Comparison of Total Energy and Non Active Energy by EPA

There are a variety of methods of improving BC efficiency and reducing energy consumption. One possible method of reducing energy consumption in BCs that have a transformer is to use a control chip with a built-in timer. In those BCs, the core losses of the transformer are fixed even when the BC produces little or no power. To limit those losses, the control chip could stop power from flowing to the transformer for large periods of time. When needed, a pulse from the timer every few minutes could direct the control chip to take a short burst of energy from the mains. In maintenance mode, the charge regulator would take very little energy from mains most of the time, yielding a more efficient BC. In active mode, when the battery needs continuous charging, the BC could charge continuously instead of waiting for the timer. Further, if the control chip itself were to consume very little power (from 0.1 mW to 1 mW), then the chip could draw power from the battery rather than from mains. If the power drawn is that low, the chip would not significantly discharge the battery. A key benefit in this design is that the battery-powered chip can signal the BC to electrically disconnect from the mains, hence drawing no power, unless it is charging the battery. A challenge in this design approach would be meeting safety requirement by electrically isolating the battery from the mains as well as powering the chip when the battery is almost empty.

One factor enabling more efficient chargers is newer battery chemistries. For newer chemistries, such as Li-Ion, that have more demanding charging requirements, the BC inherently needs to have a control chip, and it is relatively simple for the chip to direct the BC to be energy efficient while also meeting battery-charging requirements.

Issue 37: *DOE invites comment on different types of BCs in the market.*

3.4.4 Efficiency Testing

The efficiency of most BC and EPS units combined with consumer usage patterns, determines the overall efficiency of a BC or EPS. Since these two types of power converters are unique in terms of efficiency at different power levels and use patterns, DOE published two final rule test procedures, one for BCs and one for EPSs,[n] on December 8, 2006. 71 FR 71368. The test procedures adopted are closely based on the test procedures developed by EPA for the ENERGY STAR standards for Battery Charging Systems and External Power Supplies.

The EPS test procedure evaluates EPSs in active mode and no-load mode. The active mode test measures the average of efficiency measurements at four different load conditions: 25

[n] DOE's proposed test procedures are based on test procedures developed by EPA for the ENERGY STAR program: "Test Methodology for Determining the Energy Performance of Battery Charging Systems," 2005, and "Test Method for Calculating the Energy Efficiency of Single-Voltage External Ac-Dc and Ac-Ac Power Supplies," 2004.

percent, 50 percent, 75 percent, and 100 percent of maximum rated output power. In addition, the test procedure also measures power consumption of the EPS in no-load mode.

The BC test procedure is more complex because BC efficiency is inherently linked to the battery it is designed to charge. The BC and battery are therefore evaluated together as a battery charging system to determine the amount of energy that is passed from the mains to the consumer product via the BC and battery (see Figure 3.19).

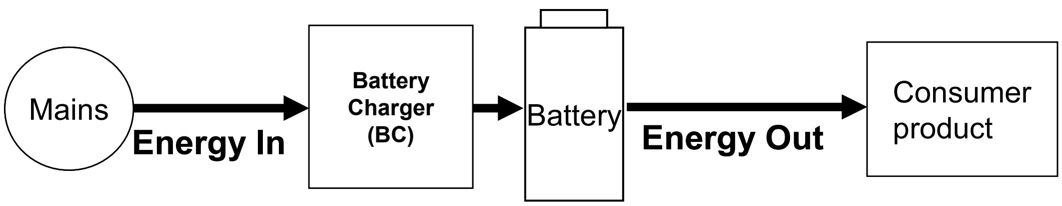

Figure 3.19 Energy Transfer in a battery charging system

The BC test procedure measures the sum of the power consumed by the BC in maintenance mode and no-load mode over specified time periods. That power consumption, called the accumulated non-active energy, or E_a, is normalized by the battery energy E_b, in watt-hours produced by the battery at a constant current of 0.2C from maximum voltage to cut-off voltage.[o] Active-mode power consumption is not included as an energy input to the BC test procedure, because battery charging devices spend little time in active mode, which constrains the energy savings opportunity. Energy input and output are combined into an efficiency metric called the "non-active energy ratio" or ER:

[o] Manufacturers specify a battery capacity, C, in ampere-hours and a battery cut-off voltage. 0.2C is a current, in amperes, as a fraction of C.

$$ER = \frac{E_a}{E_b}$$ **Eq. 3.9**

where E_a is the energy consumed in watt-hours by a BC that spends 36 hours in maintenance mode and then 12 hours in no-load mode.[p] For a given battery voltage, non-active energy ratio gives a relative measure of the efficiency of a BC system.

3.4.5 External Power Supply Energy Consumption Test Data

During the development of the ENERGY STAR EPS specification, EPA tested the energy performance of 190 EPSs. These EPSs were submitted by manufacturers or purchased from retailers and therefore the sample may not be fully representative of the market in any one year, but it can be used to develop an initial picture of EPS efficiencies in the market. EPA tested the EPS in two modes: no-load mode and active mode. In no-load mode, the power consumption from mains was recorded while the EPS was disconnected from a load. In no-load mode all of the input power was consumed by the EPS and dissipated as waste heat. EPA also measured efficiency in active mode while the EPS was delivering power to a test load. The test load was adjusted for four efficiency measurements at 25%, 50%, 75%, and 100% of maximum rated output current. Those four efficiency measurements were averaged to determine the average efficiency of the EPS in active mode.

3.4.5.1 No-Load Mode Energy Consumption

Energy is consumed by EPSs in no-load mode although no power is delivered to a consumer product. The EPA's database recorded no-load mode power consumption for the 190 EPS units tested (see Figure 3.20). There does not appear to be any relationship in the test data between maximum rated output power and no-load mode power consumption. Over the entire

[p] The test measurement durations of 36 and 12 hours were developed by consensus between EPA and stakeholders.

range of rated power in the database, there are EPSs that consume less that 0.5 W and others that consume more than 2 W in no-load mode. This suggests that there is the potential to reduce no-load power consumption in the market, which would contribute to energy savings.

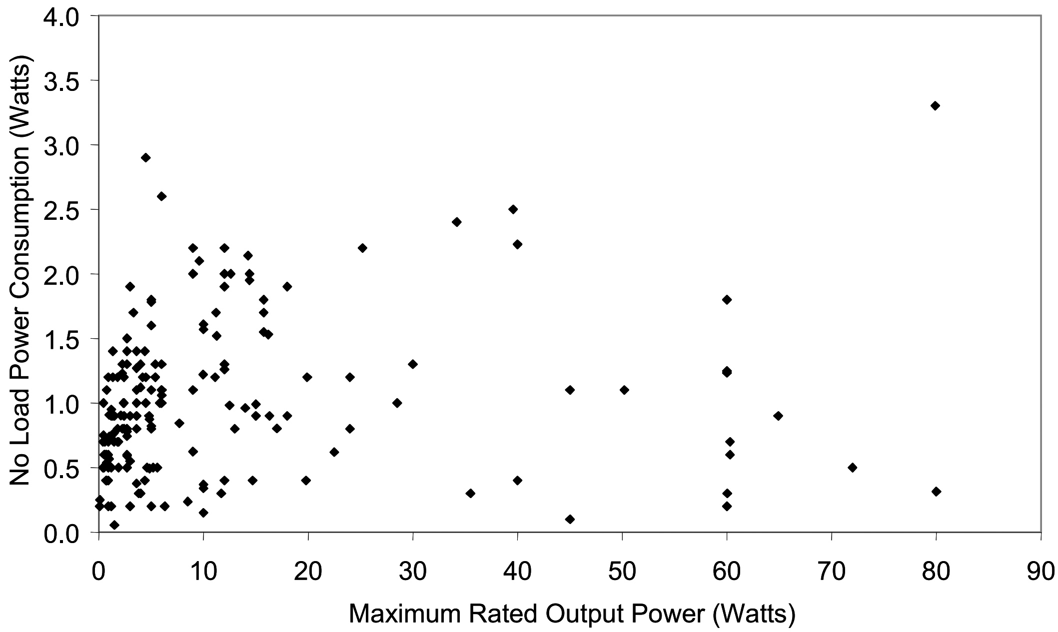

Figure 3.20 No-Load Mode Energy Consumption of EPSs in the Environmental Protection Agency Database

3.4.5.2 Active Mode Energy Consumption

Figure 3.21 plots average efficiency against rated output power for each of the 190 EPSs in the sample. Table 3.3 summarizes these data. The efficiencies shown are an average of EPS efficiency at the four loading points, as designated in the DOE's test procedure: 25 percent, 50 percent, 75 percent, and 100 percent of maximum rated output power.

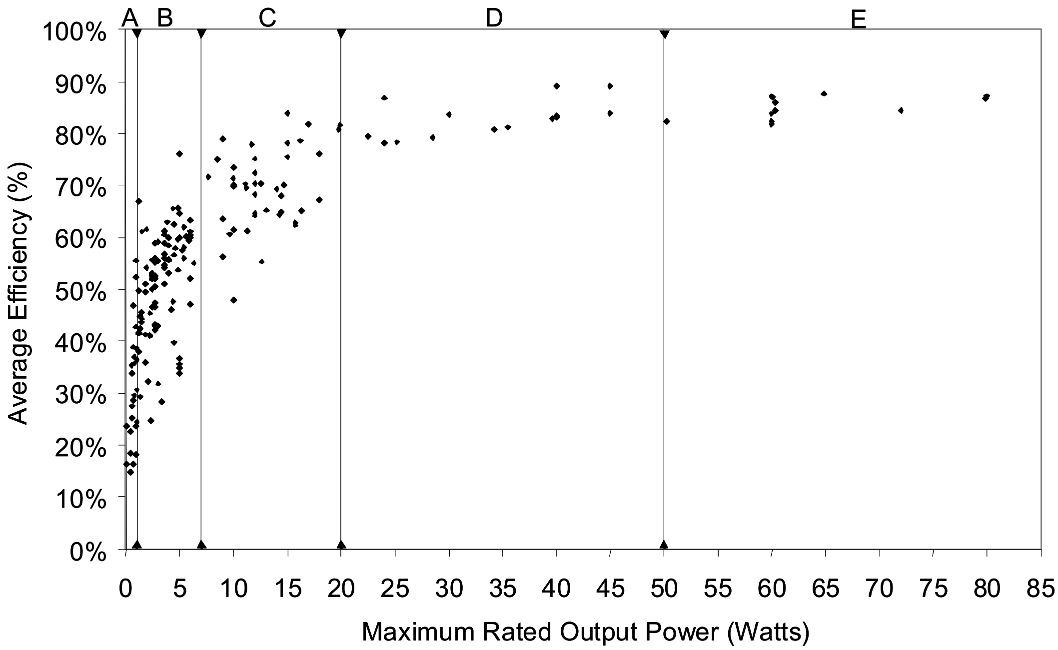

Figure 3.21 Energy Efficiency Data for EPSs, Divided Into Groups A, B, C, D, and E

Table 3.3 Median Efficiency and a Comparison of Efficiencies for the Most-Efficient and Least-Efficient EPSs in the Environmental Protection Agency Database

Group	Rated output power	Median Efficiency	Efficiency of Most Efficient EPS	Efficiency of Least Efficient EPS	Difference in Efficiency
A	0 to 1 W	29%	52%	16%	36%
B	>1 to 7 W	53%	70%	27%	42%
C	>7 to 20 W	70%	82%	53%	29%
D	>20 to 50 W	83%	88%	79%	10%
E	>50 to 80 W	85%	87%	82%	5%

DOE divided the data into five groups according to each model's rated output power, as shown in Figure 3.21 and listed in Table 3.3. DOE selected these groups after carefully reviewing how efficiencies and EPS power consumption vary across the range of rated output power represented in the sample.

To illustrate potential energy savings, Table 3.3 compares the average efficiency for the most efficient EPS and least efficient EPS in each of the different groups.[q] In groups A, B, and C, the difference in the range of efficiencies is wide, from about 30 percent to 40 percent, but in groups D and E, the difference is more narrow, or less than 10 percent.

Issue 38: *DOE invites comments on which efficiency levels are common in the market and whether the median values listed in Table 3.3 are representative of the market.*

The trends in the graph are indicative of current technology and costs. For instance, the high efficiencies in groups D and E are necessitated by the relatively large amounts of heat generated at higher output power ratings. Heat generated by inefficiency can be significant, especially at high output power, because it can cause technical challenges. Therefore, the technical demands motivate designers to pursue higher efficiency. That said, higher efficiency designs come at a cost premium, and the market generally calls for EPS with the lowest possible cost. Thus, the narrow range of efficiencies in groups D and E reflects these technological and market pressures.

Issue 39: *DOE invites comments on the relationship between cost and efficiency for EPSs at different output power ratings.*

The comparison of the differences between the most efficient and the least efficient EPS in Table 3.3 suggests potential energy savings based upon existing technologies in the market, as represented by the dataset. For instance, there is a wide range of efficiencies in groups A, B, and C (36 percent, 42 percent, and 30 percent, respectively), compared to groups D and E (10 percent

[q] "Most Efficient EPS" is the average of the three highest EPS active-mode energy efficiency results in a given group. "Least Efficient EPS" is the average of the three lowest EPS active-mode energy efficiency results in a given group.

and 5 percent, respectively). This indicates that there is more potential room for improving the energy efficiency for EPSs with lower maximum rated output power.

The difference between the input power and output power is the power consumption of the EPS itself. Figure 3.22 plots EPS power consumption against rated output power for the same 190 EPSs analyzed previously. Table 3.4 summarizes these data. The power consumption is the average of EPS power consumption at the four loading points, as designated in the DOE's test procedure: 25 percent, 50 percent, 75 percent, and 100 percent of maximum rated output power.

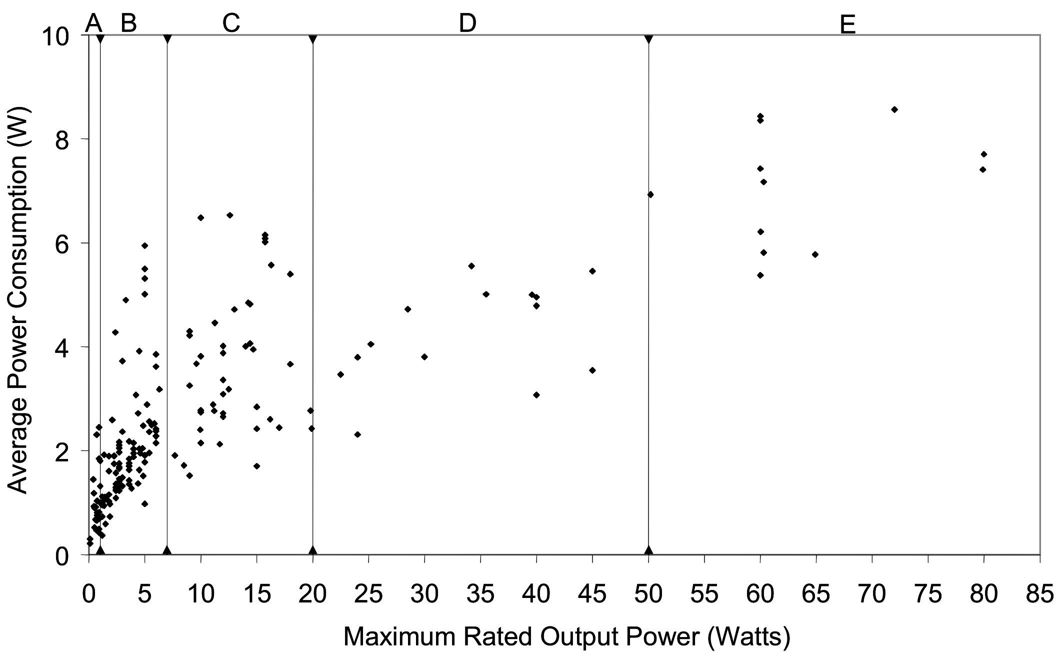

Figure 3.22 Power Consumption Data for EPSs, Divided Into Groups A, B, C, D, and E

Table 3.4 Median Power Consumption and a Comparison of Power Consumption for High-Efficiency EPSs and Low-Efficiency EPSs

Group	Rated output power	Median Power Consumption	Power Consumption of Most Efficient EPS	Power Consumption of Least Efficient EPS	Difference in Power Consumption
A	0 to 1 W	0.9 W	0.3 W	2.2 W	1.9 W
B	>1 to 7 W	1.8 W	0.6 W	5.6 W	5.0 W
C	>7 to 20 W	3.3 W	1.6 W	6.4 W	4.7 W
D	>20 to 50 W	4.4 W	2.9 W	5.3 W	2.4 W
E	>50 to 80 W	7.3 W	5.7 W	8.5 W	2.8 W

The comparison of the power consumption of the most efficient and least efficient EPS shown in Table 3.4 is another indicator of potential savings. For instance, in group B the most efficient EPS consume only 0.6 W as opposed to 5.6 W for the least efficient EPS. Thus, 5 W of power would be saved by increasing the efficiency of the least efficient EPS to the level of the most efficient EPS. By comparison, the EPS in group E all use more power than the EPS in group B; however, group E has a smaller difference in power consumption: only 2.8 W. Therefore, on a per unit basis as shown by this market data, there is more potential energy savings in group B than in group E.

Issue 40: *DOE invites comments on which power consumption levels are common in the market and whether the median values listed in Table 3.4 are representative of the market.*

Overall, the ranges of power consumption are smaller for groups A, D, and E—between 1.9 and 2.8 W—and larger for groups B and C—between 4.7 and 5.0 W. Thus, in groups A, D, and E, there is less wattage to be saved by potential improvements, compared to the larger energy savings opportunity from 1 W- to 20 W-rated output power.

DOE's analysis of the EPA database indicates potential savings based on the EPS in the current market. Additional savings comes with improving technology and shifting the market. Of the groups considered, groups B and C had the widest ranges of efficiency and power consumption. Thus, on a per-unit basis, improvements to EPSs with a maximum rated output power between 1 W and 20 W offer the most potential energy savings.

3.4.5.3 Metric for EPS Efficiency and Energy Consumption

EPSs offer energy savings opportunities in both active mode and no-load mode. The DOE's test procedure measures active mode efficiency at four loading points and combines them to create an average active mode efficiency. 71 FR 71368. The DOE's test procedure also measures no-load mode energy consumption. If there is a positive determination, then DOE will evaluate energy conservation standards for EPSs using one metric that accounts for both active mode efficiency and no-load mode energy consumption.

Issue 41: *DOE invites comments on how to develop a single metric that combines active mode efficiency and no-load mode power consumption.*

3.4.6 Technology Options

Both BCs and EPSs both offer several potential opportunities for improving energy efficiency. For EPSs, efficiency can be improved by replacing specific parts with more efficient alternatives and using switching regulators at higher wattages. Generally, the proposed technology options improve efficiency and reduce energy consumption in both active mode and no-load mode. For BCs, the greatest opportunities are from control circuits that minimize power consumption in maintenance mode and no-load mode, as well as using switching regulators instead of linear regulators. These opportunities, or technology options, are summarized in Table

3.5. The table summarizes these options, sometimes dividing between unregulated line-frequency EPSs and regulated switching EPSs. This table also indicates whether the measure to improve efficiency has a major or minor impact on the device performance. The text following Table 3.5 discusses each of these technology options in detail.

Table 3.5 Technology Options for BCs and EPSs and the Significance of Their Impact on Improving Efficiency

Technology Option	Impact on EPS Efficiency		Impact on BC Efficiency
	line-frequency	*switching*	
Improved transformer/choke core	Major	Major	Major
Heavier gauge and more turns of transformer/choke wire	Major	Major	Minor
Use switching regulator instead of linear regulator	Major at higher wattages Minor at lower wattages		Major at higher wattages Minor at lower wattages
Better pulse-width-modulated (PWM) controller	N/A	Major in no-load	Major
Reduce operational duty cycle for lighter loads	N/A	Major	Major
Improved diodes	Minor	N/A	Minor
Improved circuit layout	N/A	Minor	N/A

3.4.7 External Power Supplies Efficiency Improvements

The greatest opportunities for improving EPS efficiency are in the components and processes where both no-load and active mode losses are largest. Those losses are different for different power levels, as well as for unregulated line-frequency EPS versus regulated switching EPS.

For line-frequency EPS, the largest losses are in the transformer, particularly at light loads. The most effective means to reduce transformer power loss at light loads is to select a transformer with higher quality core material and a lower level of magnetic induction. At line frequency, the transformer core material typically is thinly laminated steel that is alloyed with silicon. The amount of silicon affects the core power loss and the cost of the transformer. Core performance is enhanced by magnetically orienting the grain structure in the metal. The industry standard for common non-oriented-grain-structure core material ratings range from M19 to M45, with the lower number having fewer electrical losses. M6 core steel is used in an energy efficient EPS transformer because it is a high-quality grain-oriented core steel that has very low electrical losses.

The second important factor contributing to core loss is the level of magnetic induction. Core losses are measured in watts per pound (W/lb), and induction is given in kilogauss (kG). Induction levels in these devices typically range between 10 kG and 15 kG. Reducing the induction level will reduce the core losses, but it will increase the winding losses. Reducing the induction requires more wire turns and therefore a larger core for a given power rating. The trade-off of these improvements is the increased size and weight of the transformer, and ultimately the EPS. Table 3.6 shows the effects of material type and induction on core loss. Power loss in the transformer core can be reduced by an order of magnitude by increasing the quality of the core steel and reducing the level of magnetic induction: 0.28 W/lb versus 3.1 W/lb.

Table 3.6 Quality of Core Steel and Level of Magnetic Induction

Steel	Core Losses at Various Levels of Magnetic Induction		
	10 kG	12 kG	15 kG
M6	0.28 W/lb	0.40 W/lb	0.60 W/lb
M19	0.85 W/lb	1.2 W/lb	2.0 W/lb
M45	1.4 W/lb	1.9 W/lb	3.1 W/lb

Additionally, some primary transformer windings have high resistance to prevent failure in the case of overload conditions. Using a separate fuse to prevent failure would allow the transformer to have a lower winding resistance, thus reducing electrical losses.

A large potential source of energy loss in a high-frequency EPS is the choke, similar to the transformer in line-frequency EPSs. Methods of improving the energy efficiency of chokes are similar to those for improving transformers, that is, improving the core material and increasing the turns of copper windings.

At higher power ratings, a switching regulator is generally a more efficient alternative to a line frequency regulator, because it can be made to transfer only the needed amount of energy. In a linear regulator, power is continuously taken from the mains, and excess power is dissipated as heat in the pass device, previously show in Figure 3.7. Instead, in the case of a switching regulator, a chopper changes the duty cycle when more power is needed, in response to the power demands of the load, previously show in Figure 3.9. By only taking the needed power, the switching regulator dissipates less energy and therefore is generally more efficient than the linear regulator, especially at higher wattages. At lower wattages, however, neither regulation technology has a clear efficiency advantage. This is partly because the switching regulator circuit components themselves consume some energy, regardless of the output power of the device. At lower wattages, this fixed energy consumption is a more significant proportion of total EPS energy consumption.

Another major opportunity for efficiency improvement is the controller. By making the pulsed-wave-modulated signal that controls the chopper, the controller determines how much energy the switching regulator circuit consumes. The controller can adjust the input power of the switching regulator to closely match that of the load. Under no-load and light load conditions, such as 25 percent or less of rated maximum load, the controller can reduce the frequency of operation, reduce the duty cycle, or skip entire cycles. Each of these steps will impact the energy consumption of an EPS. Additionally, the PWM controller itself consumes power. Reducing the power consumption of the controller will further reduce losses in no-load mode.

Diodes are another source of loss for DC line-frequency EPSs. These losses increase as the output voltage decreases, and become particularly significant below 9 V. Part of the power consumed by a diode is the product of the current flowing through the diode multiplied by the voltage drop across it. When a line-frequency EPS is designed for low-output voltage, that drop can become significant. Using Schottky diodes[r] reduces the voltage drop across the diodes, thus improving efficiency of the device. Conventional diodes have a voltage drop of about 0.7 V, which can be reduced to about 0.4V through the use of Schottky diodes.

[r] A Schottky diode is a metal-semiconductor diode with a smaller voltage drop than a conventional diode which hence consumes less power.

Issue 42: *DOE invites comments on these component technology options and would welcome input on other approaches to improve efficiency through the components.*

3.5 SECTION THREE REFERENCES

The following is the reference for information presented within this section:

[1] The most recent average residential retail electricity price in 2004 is $0.0897/kWh, according to the Energy Information Administration (EIA), 2006. (Last accessed December 6th 2006.) <http://www.eia.doe.gov/cneaf/electricity/epa/epat7p4.html.> The December 6, 2006 information from this website is available in Docket #EE-2006-DET-0136. For more information, contact Brenda Edwards-Jones at (202) 586-2945.

4. COVERAGE AND PRODUCT CLASSES

4.1 INTRODUCTION

This section contains background information on the scope of coverage of other programs relating to BC and EPS, and raises questions concerning the scope of coverage associated with the DOE's analysis of BC and EPS. While EPCA provided clear definitions of a BC and an EPS, DOE recognizes that in certain instances, the distinction between a BC and an EPS may not always be clear. For some power converting devices, such as those powering laptop computers or hand-held video cameras, the power converter can both charge a battery and operate the consumer product, even if the battery is completely discharged or removed. For these devices, which could understandably be classified as both a BC or an EPS according to the EPCA definitions, DOE will review stakeholder comments on this issue, and work cooperatively with stakeholders to develop clear guidelines from which to develop appropriate product classifications.

This section also addresses proposed product classes for BCs and EPSs. In view of section 325(q) of EPCA, DOE generally divides covered products into classes by (1) the type of energy used and (2) the capacity of the product or any other performance-related feature that justifies different standard levels, such as features affecting consumer utility (42 U.S.C. 6295(q)). For BCs and EPSs, the type of energy used in all designs and models is electricity, so the first criterion is not used to differentiate the product classes. The second criterion, encompassing capacity or any other performance-related feature, does apply, and there are several approaches DOE could follow in establishing product classes for BCs and/or EPSs. This section discusses DOE's preliminary findings with respect to product classes, and requests stakeholder comment on these findings.

4.2 PRODUCT DEFINITIONS

4.2.1 EPCA Definitions

Section 135(a)(3) of EPACT 2005 amended section 321 of EPCA by adding subsection 321(32), which defines the term “battery charger” as a “device that charges batteries for consumer products, including battery chargers embedded in other consumer products.” (42 U.S.C. 6291(32)) Similarly, section 135(a)(3) of EPACT 2005 also amended section 321 of EPCA by adding subsection 321(36), which defines the term “external power supply” as “an external power supply circuit that is used to convert household electric current into DC [direct current] or lower-voltage AC [alternating current] to operate a consumer product.” (42 U.S.C. 6291(36)) DOE adopted both of these definitions in its final rule notice published on December 8, 2006. 71 FR 71365-71366.

While these EPCA definitions provide some clarity as to which devices should be classified as a BC and which should be classified as an EPS, DOE recognizes that there are many consumer products (e.g., laptop computers, video cameras, etc.) that incorporate both a BC and an EPS under the scope of the EPCA definitions. In these cases, DOE needs to determine whether these consumer products would be subject to two standards or whether a single standard can be applied with criteria developed to provide clear guidance as to whether the consumer product is classified as a BC or EPS. In addition, DOE was also granted authority under EPACT 2005 (as discussed in section 2.1 of this document) to establish two standards for one product that serves two major functions. Therefore, DOE will need to determine whether some power converting devices, such as those powering laptop computers or hand held video cameras, where the power converter can both charge the battery and operate the consumer product is performing two major functions (i.e. those functions of a BC and those of an EPS). One product serving two major functions could be subject to two standards or may be better classified as either a BC or an EPS, and have a single standard apply. If it becomes clear that the classification as a single product with a single standard is appropriate, then DOE will need to develop clear criteria and guidance by which stakeholders would be able to classify their consumer product as either a BC or an EPS.

For this preliminary market and technology assessment, DOE divided those products that might be classified as a BC and an EPS using the ENERGY STAR definitions (see section 4.2.2.1). DOE's interpretation of the principal difference between a BC and an EPS according to ENERGY STAR concerns whether the power converting device is able to operate the consumer product, independent of the battery. In other words, if the power converter can operate a consumer product when the batteries are removed (or when the batteries are installed but completely discharged), then that power converter is considered to be an EPS. If, on the other hand, a consumer product is not fully operational when the battery is removed or is completely discharged, even when the power converter is connected to the device and plugged into the wall outlet, then the device is considered to be a battery charger. DOE is inviting stakeholders to comment on this interpretation, including whether it would be in conflict with any of the conventional classifications of products, or existing national or international standards and/or voluntary programs.

Issue 43: *DOE invites comment on this preliminary differentiation of the BC and EPS markets, based on the ENERGY STAR definitions, including whether this interpretation is in conflict with any national or international standards or voluntary programs.*

4.2.2 Existing BC and EPS Program Scopes of Coverage

For the draft analyses published in this document, DOE classified BCs and EPSs in a manner consistent with the ENERGY STAR definitions. DOE used this initial division because the ENERGY STAR product classification system is used widely after being developed over several years in consultation with a broad range of stakeholders.

DOE also reviewed a range of existing regulatory and non-regulatory programs that specify performance criteria for BC and EPS. DOE found that, in some cases, these programs use different definitions of BCs and EPSs, and as a result, include different consumer product types within their scopes. ENERGY STAR is the basis for several BC and EPS programs, both voluntary and mandatory. China, Australia, and New Zealand all have the same product definitions and scopes of coverage for BCs and EPSs as ENERGY STAR, while California, the European Union, and South Korea all use different definitions which encompass somewhat different sets of product types within their scopes of coverage. These programs can use different factors to distinguish devices that might be classified as EPSs and those that might be classified as BCs. Some of those factors include:

- Whether the consumer product does or does not have batteries, and whether those batteries are integral to the device or designed to be removed by the consumer for charging;
- Whether the power converter has a battery chemistry switch, a type selector switch, an indicator light, or a state of charge meter; and
- Whether a power converters' primary function is to charge batteries.

Issue 44: *DOE invites comment on these and any other factors it should take into consideration in determining how to classify devices appropriately.*

Issue 45: *DOE invites comment on whether it would be appropriate to classify products that serve two major functions in a separate product class and evaluate those products considering two energy conservation standards, one addressing each major function. DOE was recently granted authority to establish two standards for one product that serves to major functions by EPACT 2005, section 135(c)(3) which amended section 325(o)(5) of EPCA. (42 U.S.C. 6295(o)(5))..*

4.2.2.1 ENERGY STAR

ENERGY STAR defines an EPS as a:

single-voltage external ac-dc or ac-ac power supply that is designed to convert line voltage ac input into lower voltage ac or dc output; is able to convert to only one dc output voltage at a time; is sold with, or intended to be used with, a separate end-use product that constitutes the primary load; is contained in a separate physical enclosure from the end-use product; is connected to the end-use product via a removable or hard-wired male/female electrical connection, cable, cord or other wiring; does not have batteries or battery packs that physically attach directly (including those that are removable) to the power supply unit; does not have a battery chemistry or type selector switch AND an indicator light or state of charge meter; and; has nameplate output power less than or equal to 250 watts.[1]

For the purpose of ENERGY STAR, this definition includes devices that power ink-jet printers, notebook computers, and mobile phones, among a broad range of consumer products. The Department recognizes that certain power conversion devices that perform the function of both an EPS and charging a battery embedded in a consumer product may be more correctly classified as both an EPS and a BC, per the EPCA definitions.

ENERGY STAR defines a BC as a:

> device intended to replenish the charge in a rechargeable battery. The battery charger will connect to the mains at the power input and connect to the battery at the output. The charger may be comprised of multiple components, in more than one enclosure, and may be all or partially contained in the end-use product.

ENERGY STAR further clarifies that the battery charging systems specification applies to: motor-driven battery charged products; products whose principal output is heat, light, or motion; battery charging systems intended to replace standard sized primary alkaline cells; and other products with detachable batteries and stand-alone battery chargers whose designs are not covered by the external power supply specification. To qualify for the battery charging systems specification, the battery may be either separable from or integral to the end-use product.[2]

The ENERGY STAR specification applies to BCs with a nameplate input power between 2 and 300 W and that charge batteries with voltage less than 42 V. It does not apply to chargers that use an inductive coupling system nor to chargers that have a secondary functionality that draws power while the battery is being charged or maintained. This definition includes devices that power such products as handheld rechargeable vacuum cleaners, power tools, some digital cameras, some camcorders, and stand-alone battery chargers that power rechargeable standard-size batteries.

4.2.2.2 California Energy Commission

The revised California Energy Commission's (CEC) regulations, adopted in July of 2006, use the same definition of an EPS that ENERGY STAR does, although it explicitly excludes medical devices[25]. The CEC regulations do not, however, exclude BC from the EPS scope of coverage. Therefore, a power conversion device that ENERGY STAR would consider a BC, such as a charger for a power tool, would be considered to be an EPS under the CEC's definition.

CEC is currently in the process of developing a BC test procedure. This proposed test procedure would cover "those electronic devices with a battery that are normally charged from ac line voltage through an internal or external power supply and a dedicated battery charger" as well as "those devices whose primary function is to charge batteries." The CEC clarifies that "this scope is meant to cover those battery charger systems found in the residential and commercial sectors that operate on single-phase voltage and have a nameplate ac rating of less than 2 kW."[3]

Under the CEC's test procedures (as currently proposed), power conversion systems for products in some consumer product categories would be tested as both BCs and EPSs. For example, a power conversion system for a notebook computer and a battery charging system for some power tools would be tested under both the BC and EPS test procedures. By extending the nameplate power rating for BCs to 2kW, it includes many devices that may not be covered under the ENERGY STAR BC test procedure, such as battery chargers for golf carts, but does not include three-phase chargers.

4.2.2.3 European Union

The EU has adopted a scope of coverage for EPSs somewhat similar to California's in that it includes almost all EPSs, regardless of the end use. It also does not exclude BCs from its EPS definition, nor does it create a separate scope of coverage for BCs. Within the scope of coverage are single voltage external AC-DC and AC-AC power supplies for electronic and electrical appliances, including ac adapters, battery chargers for mobile phones, domestic appliances, power tools and computer equipment, in the output power range 0.3W to 150W. As the name implies, external power supplies are contained in a separate housing from the end-use devices they are powering. This specification does not cover DC-DC power supplies, or any internal power supplies (those contained inside the product)." Adapters with multiple output terminals and chargers that charge via induction are also excluded. The EU includes within its EPS scope devices that power anything from a printer to a power tool.[4]

4.2.2.4 South Korea

South Korea's EPS scope of coverage defines EPSs as "external devices that convert 110-220V input AC voltage to output DC voltage." It defines BCs as "charging devices for power source supply for mobile phones." This EPS scope includes devices that convert power for many different types of products, such as printers, power tools, and electric toothbrushes.[5]

4.2.3 Comparison of Scopes of Coverage

The scope of coverage in the ENERGY STAR, CEC, EU and South Korean BC and EPS programs appear to have overlap. Table 4.1 shows the similarities and differences between the ENERGY STAR, California, the European Union, and South Korea programs scopes of coverage. ENERGY STAR separates EPS from BC by considering whether a product has an integral battery or removable battery packs, whether the end-use product powered by the battery produces heat, light, or motion, and whether the device has a battery type selector switch and indicator light. ENERGY STAR considers those devices that charge a battery excluded from the EPS definition, and instead, they are classified as BCs. The CEC uses the same EPS definition as ENERGY STAR, but without the provision of exclusions for battery charging devices used with products that produce heat, light, or motion. The CEC's draft BC definition is applied to products that charge batteries, regardless of any power conversion functionality. The EU, like the CEC, considers the power conversion functionality of a device, regardless of its battery charging capabilities, but unlike the CEC, the EU is not developing a separate standard for battery charging. South Korea considers the power conversion functionality of devices within given voltage ranges, and only considers battery charging functionality in the case of mobile phone chargers.

Table 4.1 Comparison of Scopes of Coverage for Existing BC and EPS Programs

Power Converter Description	Example Products	ENERGY STAR	CEC	European Union	South Korea
Device that converts AC power but does not charge a battery	• LCD monitors • Printers • Scanners	EPS	EPS	EPS	EPS
Device used for battery charging or direct power delivery	• Mobile phones • Notebook computers • Some digital cameras	EPS	EPS and BC	EPS	EPS (BC for mobile phones only)
Device that charges a battery used with a product that produces heat, light, or motion	• Some power tools • Personal care products • Portable vacuums	BC	EPS and BC	EPS	EPS
Device used with products with detachable batteries and stand-alone chargers	• Some power tools • Some digital cameras • Some toys	BC	BC	Not included	Not included
Device that recharges standard size replacement cells (AA, C, etc.)	• Used with some digital cameras and many other small consumer electronics devices	BC	BC	Not included	Not included
Device that recharges batteries with input power between 300 W and 2 kW	• Golf carts • Forklifts • Scooters • Motorized Wheelchairs	Not included	BC	Not included	Not included

Sources: Adapted from U.S. Environmental Protection Agency, 2006; U.S. Environmental Protection Agency Battery Charger Final Specification*, 2006; U.S. Environmental Protection Agency* External Power Supply Final Specification *2006; California Energy Commission* Revised Appliance Regulations *2006; California Energy Commission* Draft 2 Energy Efficiency Battery Charger System Test Procedure; European Union Code of Conduct *200; Korea Energy Management Program 2006*

As observed in Table 4.1, the programs are not consistent in their treatment of power conversion devices used for battery charging and direct power delivery like those associated with mobile phones and notebook computers. ENERGY STAR and the EU consider these power conversion devices to be EPSs, while South Korea considers those power conversion devices that power notebook computers to be EPSs but those that power mobile phones to be BCs. California is proposing to regulate devices that both convert and charge a battery under both BC and EPS efficiency standards. A similar divergence in coverage can be seen with devices that charge a battery used with a product that produces heat, light, or motion, such as personal care products and some power tools.

The EU and South Korean programs do not cover devices used with products with detachable batteries and stand-alone chargers such as digital cameras and some power tools, devices that recharges standard size replacement cells (e.g., "AA," "C," etc.) such as those used with some digital cameras and other small consumer electronic devices, or devices that recharges batteries with input power between 300 W and 2 kW including vehicles such as golf carts, fork lifts, and motorized wheelchairs. ENERGY STAR and California both define devices in the first two categories as BC, but only California extends coverage to devices that recharge batteries with input ranges over 300 W.

Issue 46: *In the context of the definition of a "consumer product" contained in 42 USC 6291(1), stakeholders are invited to provide detailed comments on DOE's scope, including identifying any preferred approach, and the advantages and disadvantages of other approaches. Stakeholders are invited to identify and explain justification for specific products that DOE should address or omit from its determination analysis.*

4.3 PRODUCT CLASSES FOR BATTERY CHARGERS

DOE recognizes that there are several capacity- and performance-related features of BCs that could be used to classify products, including the charging method it employs (i.e., continuous charging or terminating charging), the voltage of the battery or batteries it is intended to charge, and/or the battery chemistry. In this document, DOE is proposing to establish product classes based on battery voltage, similar to how this issue was handled by EPA in the ENERGY STAR Battery Charging Systems standard.[a]

In developing a preliminary proposal for product classes, DOE reviewed two BC datasets developed by EPA using the ENERGY STAR test procedure (see sections 3.4.3 and section 3.4.4). These datasets recorded the energy ratio of more than 100 battery chargers for consumer electronic devices. The data are presented in this report in two graphs; the first, Figure 4.1 plots the data by consumer product type; and the second, Figure 4.2 plots the data by charging method. In both figures, lower energy ratios indicate higher efficiency BCs.

[a] What ENERGY STAR and EPA refer to as "Battery Charging Systems" pertains to the same products DOE refers to as "Battery Chargers".

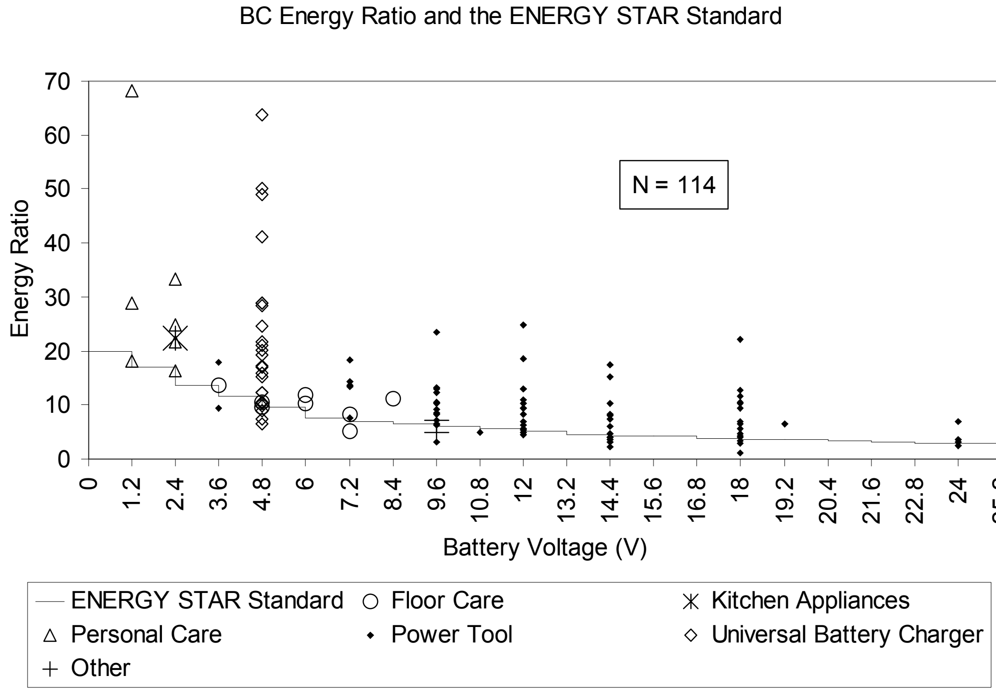

Figure 4.1 BC Energy Ratio for Different Consumer Products

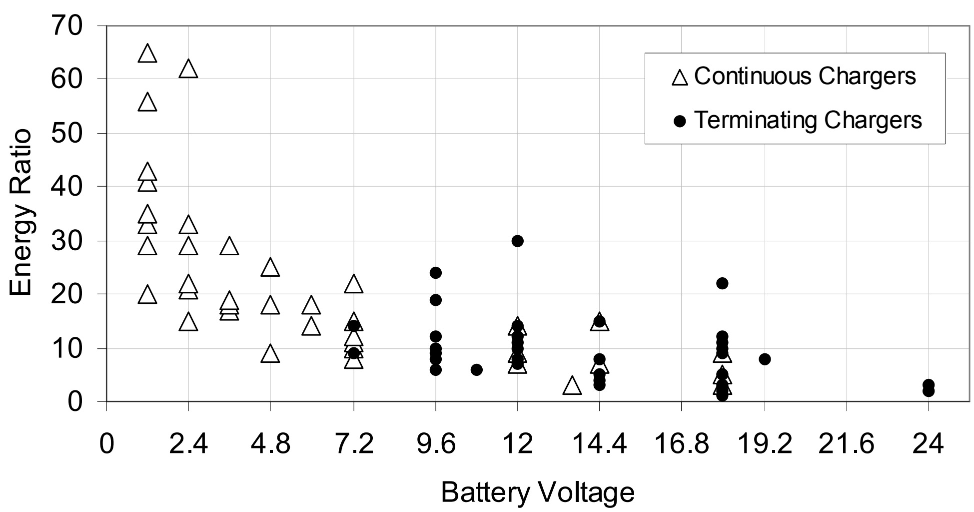

Figure 4.2 BC Energy Ratio for Terminating and Continuous Chargers.

The data show that energy ratio decreases (i.e., the battery chargers become more energy-efficient) as battery voltage increases. Therefore, DOE proposes to use battery voltage as a characteristic around which it will establish product classes. Looking carefully at the data in Figure 4.2, there does not appear to be any clear difference in efficiency between the type of charger (i.e., continuous or terminating) and the energy ratio. For example, at 7.2 volts or at 18 volts, there are a range of energy ratios of both continuous and terminating chargers – one charging method is not inherently more efficient than the other. Therefore, while DOE recognizes that these two types of chargers have different charging regimens; DOE is not proposing to establish separate product classes for BC by charging method. This approach is consistent with the ENERGY STAR program, which did not establish discrete product classes or set different program requirements by charging method.

In addition, while recognizing that different battery chemistries will have different charging requirements; DOE is not proposing to establish or subdivide BC product classes by chemistry for two reasons. First, newer chemistries entering the BC market, such as Li-ion, tend to consume little or no power in maintenance mode and therefore are already more efficient than more common chemistries, such as NiCd and NiMH. Secondly, the ENERGY STAR program, which was a public-participative process spanning several years, did not find it necessary to make a distinction by chemistry.

Issue 47: *DOE invites comment on differentiating product classes by battery chemistry; specifically on addressing different chemistries currently in the market: nickel-cadmium (NiCd), nickel-metal-hydride (NiMH),lead-acid, and lithium-ion (Li-ion).*

DOE is therefore proposing in this draft document to base product classes around battery voltage only. Within this context, DOE is considering two possible approaches. First, DOE is considering to propose having just one product class for all BCs, and establishing one equation that would be a function of voltage and would establish the required energy ratio at any battery voltage. This approach is similar to that of the ENERGY STAR program, however instead of having 20 step values, binned by battery voltage (see Figure 4.1), DOE is proposing to have simply one equation that would apply to all battery chargers. One alternative to this approach that DOE is also considering is to have three groups of voltages, with separate equations within each of the three voltage ranges – for example, 0 to 5 volts, 5 to 15 volts and above 15 volts.

Issue 48: *DOE invites comment on its proposal of having one or multiple product classes for BCs, and the use of a curve-fit equation to establish the required energy ratios.*

Issue 49: *DOE invites comment on whether it may be necessary to have separate product classes for continuous BCs and terminating BCs.*

4.4 PRODUCT CLASSES FOR EXTERNAL POWER SUPPLIES

Similar to BCs, DOE recognizes that there are several capacity- and performance-related features of EPSs that could be used to classify such products, including maximum rated output power, output voltage, regulation, and/or power factor correction.

In developing a preliminary proposal for product classes, DOE reviewed an EPS database developed by EPA using the ENERGY STAR test procedure (see section 3.4.5). This database encompasses the efficiency of more than 100 external power supplies for consumer electronic devices. The data are presented in Figure 4.3, which provides some differentiation of the scatter plot by type of EPS – linear-regulated, switching-regulated or unknown.

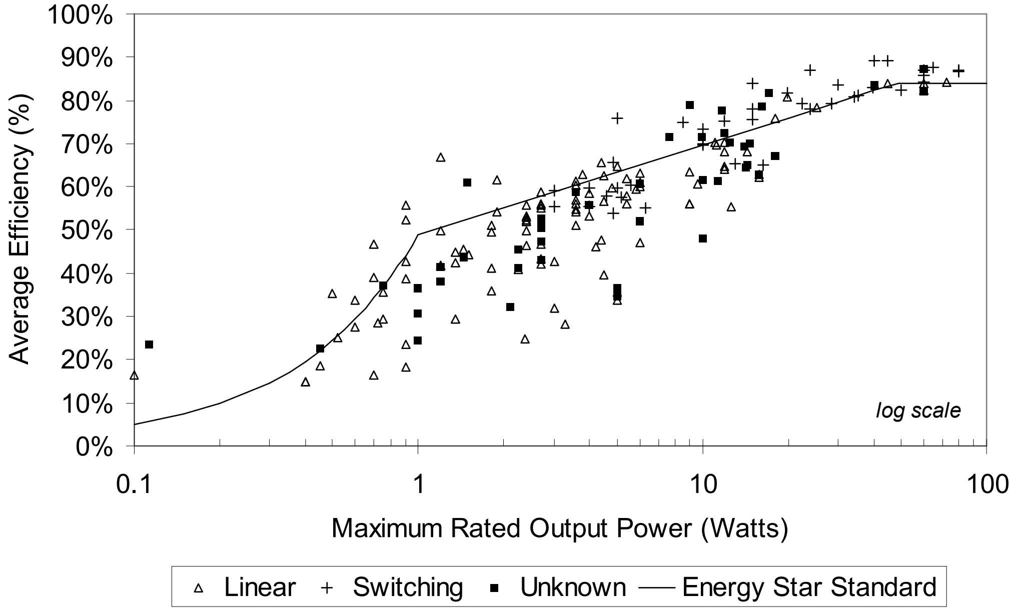

Figure 4.3 Average Efficiency versus Maximum Rated Output Power for Linear- and Switching-Regulated EPSs

Figure 4.3, which is plotted on a log-scale X-axis, shows a clear trend of increasing average efficiency with increasing maximum rated output power (i.e., watts). The efficiency values observed seem to fall into three categories – linear growth (0-1 Watts), logarithmic growth (1-20 Watts) and then relatively flat above 20 watts. This characteristic, the maximum rated output power, is the only differentiating characteristic used to establish product classes in the ENERGY STAR program. Because of the clear linkage between wattage and efficiency and the use of this characteristic by the ENERGY STAR program, DOE is proposing to establish product classes for EPS based on the maximum rated output power.

Looking at the differences between linear and switching power supplies in Figure 4.3, at power ratings greater than 10 watts, switching-regulated EPSs tend to be more efficient. And, all switching power supplies are, by their very nature, regulated power supplies (see Section 3). At wattages greater than 10 watts, DOE is not aware of any consumer utility or performance attribute which might justify separate classification of linear and switching power supplies – both linear and switching supplies would provide a regulated output. For these reasons, and because the ENERGY STAR program did not establish separate product classes for linear and switching power supplies, DOE is not proposing to use this factor as a means of classifying product.

Looking at maximum rated output power EPSs below 10 watts, the data show there is a higher percentage of linear supplies, and that the efficiencies of these linear EPSs are approximately the same as the switching EPSs. As discussed in Section 3, linear EPSs can have either a regulated or an unregulated output. And, the addition of a circuit to regulate the output voltage consumes energy, lowering the overall efficiency of the device. This group of EPSs (below 10 watts) is extremely important from a volume perspective, as it encompasses cell-phone chargers and many other small, portable consumer electronic devices. Thus, DOE is considering either establishing separate product classes for regulated and unregulated EPSs at ratings below 10 watts, or incorporating an adjustment factor into the efficiency calculation to establish a slightly lower efficiency requirement for regulated supplies below 10 watts. At this time however, DOE has no formal proposal, and is only soliciting comment from stakeholders on this issue.

Issue 50: *DOE invites comment on whether EPS below 10 watts should be classified separately into regulated and unregulated product classes.*

An EPS with a low output voltage is inherently less efficient than an EPS with a higher output voltage rated at the same maximum output power. At low voltages, losses in the diodes and the power cord coming from the EPS are more significant because of the higher currents they are accommodating. If DOE were to make a positive determination and proceed with the development of energy conservation standards for these products, DOE would not want to establish a standard that would unfairly penalize low voltage supplies by treating them the same as higher voltage supplies in the same rated wattage output group. That said, the ENERGY STAR program, which was a public process with participation by stakeholders, did not establish separate requirements for low voltage outputs and high voltage outputs. Instead, the ENERGY STAR program has one efficiency requirement, regardless of the voltage of the output. Design engineers who wish to qualify their product must work within that context, incorporating design changes in order to ensure they qualify product with low output voltage. At this time, DOE has no formal proposal to classify products with low-voltage output separately from higher-voltage outputs, and instead it is seeking stakeholder comment on this issue.

Issue 51: *DOE invites comment on differentiating EPS product classes by output voltage.*

DOE is aware that while PFC circuits will improve the overall efficiency of the electrical distribution network, they will lower the overall efficiency rating of the EPS due to the power consumed by the PFC circuit. For this reason, DOE is considering establishing different product classes or having a lower efficiency requirement for EPSs that have high power factor. DOE invites stakeholders to consider this issue and provide comments.

Issue 52: *DOE requests comment on accounting for power factor correction (PFC) in EPSs as a separate product class, an adjustment to any possible future standard or not at all.*

Considering all the aforementioned factors and requirements, DOE's draft proposal for EPS product classes is to establish only four product classes over four different maximum output power ratings, as shown in Table 4.2. The four product classes are derived from Figure 4.3 which DOE considers as having four groupings of efficiency.

Table 4.2 Four EPS product classes under consideration by DOE

Draft Proposal	Maximum Rated Output Power
EPS Product Class 1	Less than 1 W
EPS Product Class 2	1 W to less than 20 W
EPS Product Class 3	20 W to less than 50 W
EPS Product Class 4	50 W or greater

DOE is considering EPS product classes that are different than those in the ENERGY STAR program, listed in Table 4.3, which have separate product classes for active mode and no-load mode program requirements. However, both methodologies consider the same factors: maximum rated output power, average efficiency in active mode, and power consumption in no-load mode.

Table 4.3 ENERGY STAR Product Classes for Active Mode and No-Load Mode for EPSs

<table>
<tr><th></th><th>Active-Mode</th><th>No-Load Mode</th></tr>
<tr><td rowspan="3">Maximum Rated Output Power</td><td>≤ 1 W</td><td>< 10 W</td></tr>
<tr><td>>1 W up to 49 W</td><td rowspan="2">10 W to 250 W</td></tr>
<tr><td>>49 W up to 250 W</td></tr>
</table>

Issue 53: *DOE is soliciting comments from stakeholders on appropriate product classes to use for EPSs.*

Issue 54: *DOE is also soliciting comment on whether it should treat EPSs that also operate BCs embedded in consumer products in a separate product class.*

4.5 SECTION FOUR REFERENCES

The following is a list of references for information presented within this section:

[1] US Environmental Protection Agency. *ENERGY STAR Program Requirements for Single Voltage External AC-DC and AC-AC Power Supplies, Version 1.1*. Released March 1, 2006. (Last accessed March 1, 2006.) <http://www.energystar.gov/ia/partners/product_specs/program_reqs/EPS%20Eligibility%20Criteria.pdf> The March 1, 2006 material from this website is available in Docket #EE-2006-DET-0136. For more information, contact Brenda Edwards-Jones at (202) 586-2945.

[2] US Environmental Protection Agency. *ENERGY STAR Program Requirements for Products with Battery Charging System.* Released January 4, 2006. (Last accessed January 4, 2006.) <http://www.energystar.gov/ia/partners/product_specs/eligibility/bcs_elig.pdf> The January 4, 2006 material from this website is available in Docket #EE-2006-DET-0136. For more information, contact Brenda Edwards-Jones at (202) 586-2945.

[3] California Energy Commission. *Appliance Efficiency Regulations.* Revised July 2006. (Last accessed July 3, 2006.) <http://www.energy.ca.gov/2006publications/CEC-400-2006-002/CEC-400-2006-002-REV1.PDF> The July 3, 2006 material from this website is available in Docket #EE-2006-DET-0136. For more information, contact Brenda Edwards-Jones at (202) 586-2945.

[4] European Commission. Directorate-General Joint Research Centre, Institute for Environment and Sustainability. *European Code of Conduct on Energy Efficiency of External Power Supplies*. Released on November 24, 2004. (Last accessed August 3, 2006.) http://www.google.com/search?q=cache:CGfPHDGYzSEJ:energyefficiency.jrc.cec.eu.int/pdf/Workshop_<Nov.2004/PS%2520meeting/Code%2520of%2520Conduct%2520for%2520PS%2520Version%25202%252024%2520November%25202004.pdf+European+Code+of+Conduct+on+Energy+Efficiency+> Cached file. The August 3, 2006 material from this website is available in Docket #EE-2006-DET-0136. For more information, contact Brenda Edwards-Jones at (202) 586-2945.

[5] Korea Energy Management Corporation. *Energy Efficiency Programs: e-Standby Program*. (Last accessed August 3, 2006.) <http://www.kemco.or.kr/english/sub03_energyefficiency02_sub03.asp> The August 3, 2006 material from this website is available in Docket #EE-2006-DET-0136. For more information, contact Brenda Edwards-Jones at (202) 586-2945.

APPENDIX A. ISSUES FOR COMMENT

Additional items for comment can be found in a companion document entitled "Plans for Developing Energy Conservation Standards for Battery Chargers and External Power Supplies", which can be downloaded (in a PDF format) from DOE's homepage for BCs and EPSs: http://www.eere.energy.gov/buildings/appliance_standards/residential/battery_external.html

APPENDIX B. BATTERY CHARGER AND EXTERNAL POWER SUPPLY MANUFACTURERS

Company Name	Source	BC/EPS	Website	US/Foreign/ Multinational	Country HQ
Absopulse Electronics Ltd.	Advertisement in March 2004 issue of EDN magazine	BC and EPS	http://www.absopulse.com/	Multinational	Canada
AcBel Polytech Inc.	E* EPS Prospect	EPS	http://www.acbel.com/	Multinational	Taiwan
AccelRate Power Systems	PowerPulse article, 6/14/06, "AccelRate Passes "High-Speed" Charging Milestone for Advanced Lithium Batteries"	BC	www.accelrate.com	Foreign	Canada
Acme Electric Corporation (Actuant)	Hoover's Online Profile	BC and EPS	http://www.acmeelec.com/index.htm	US	United States
Actus Global Holding	Globalsources.com	BC and EPS	Not accessible	Foreign	China
AeroVironment, Inc.	E* EPS Prospect	BC	http://www.aerovironment.com/	US	United States
AGMA Power Systems	Powersupplies.net	EPS	http://www.agma.co.il/	Foreign	Israel
American Power Conversion Corp.	E* EPS Prospect	BC and EPS	http://apc.com/	Multinational	United States
Ametek Solid State Controls (Marmon Group)	Hoover's Online Profile	BC	http://www.solidstatecontrolsinc.com/index.html	Multinational	United States
Amrel Systems, LLC	E* EPS Prospect	EPS	http://www.amrel.com	US	United States
Analog Devices	PowerPulse article 5/17/06, "Analog Devices Announces Second Quarter Results"	BC and EPS	http://www.analog.com/en/index.html	Multinational	United States
Analogic Tech	iStar Database Database	BC	http://www.analogictech.com/	Multinational	United States
Anam Instruments (Shenzhen Co.)	Darnell Group, 2005	EPS	http://www.anamic.co.kr/en/index.asp	Multinational	South Korea
Anoma Electric Co., Ltd.	Darnell Group, 2005	BC and EPS	http://www.anoma.com/	Multinational	United States
Anton/Bauer	E* EPS Prospect	BC	http://www.antonbauer.com/home.htm	US	United States
Arotech	Hoover's Online Profile	BC	http://www.arotech.com/index.html	Multinational	United States
Artesyn Technologies (bought by Emerson 2/2/06)	E* EPS Prospect	BC and EPS	http://www.artesyn.com/	Multinational	United States
Asian Power Devices	E*EPS Partner	EPS	http://www.apd.com.tw/	Multinational	Taiwan
Associated Equipment Corporation	Thomas.net	BC	http://www.associatedequip.com/index.html	US	United States

Company Name	Source	BC/EPS	Website	US/Foreign/ Multinational	Country HQ
Astec (subsidiary of Emerson)	E* EPS Partner	EPS	http://www.astec.com/	Multinational	United States
Astrodyne	PowerPulse article, 4/13/06, "Astrodyne Open Frame AC-DC Powers up to 22W"	EPS	http://www.astrodyne.com/astro/default.asp?	Multinational	United States
ATLINKS USA, INC. (Thomson)	E* EPS Prospect	BC	http://www.atlinks.com/	Multinational	France
Autec	Darnell Group, 2005	BC and EPS	http://www.autec.com/	Multinational	United States
BAE Systems, Inc.	E* EPS Prospect	EPS	http://www.baesystems.com/	Multinational	United Kingdom
Bear Power Supplies	PowerPulse article, 5/25/06, "BEAR Power Supplies adds 30 W Models to Line of ac/dc Converters"	EPS	http://www.bearpwr.com/	US	United States
Behlman Electronics Inc.	Appliance Magazine Supplier Directory	EPS	http://www.behlman.com/	US	United States
Beijing Dynamic Power Co., Ltd.	E* EPS Prospect	EPS	Not accessible	Foreign	China
Best Link Business Corporation	E* EPS Partner	EPS	http://twbestlink.en.alibaba.com/	Foreign	Taiwan
Biamp	E* EPS Prospect	EPS	http://www.biamp.com/	US	United States
BIAS Power Technology, Inc.	E* EPS Prospect	EPS	http://www.biaspower.com/	US	United States
Bitrode Corp.	E* EPS Prospect	BC and EPS	http://www.bitrode.com/	Multinational	United States
Black and Decker Corporation	iStar Database	BC	http://www.blackanddecker.com/	Multinational	United States
Boundless Corporation	E* EPS Prospect	EPS	http://www.boundless.com/	US	United States
Bren-Tronics, Inc.	E* EPS Prospect	BC and EPS	http://www.bren-tronics.com/	US	United States
C&D Technologies	E* EPS Prospect	EPS	http://www.cdtechno.com/	Multinational	United States
Cadex	E* EPS Prospect	BC	http://www.cadex.com/	Multinational	Canada
Calex	Thomas.net	EPS	http://www.calex.com	US	United States
California Instruments	Appliance Magazine Supplier Directory	EPS	http://www.calinst.com/	US	United States
Canon U.S.A., Inc.	iStar Database	BC	http://www.usa.canon.com/html/canonindex.html	Multinational	Japan
Celetronix USA Inc.	E* EPS Partner	EPS	http://celetronix.com/index.htm	Multinational	United States
Chang Zhou Jinding Electric Co., Ltd.		EPS	Not accessible	Foreign	China
Charge Source (Comarco)	Hoover's Online Profile	BC	http://www.chargesource.com/	US	United States
Chekiang Jec Electronic Co., Ltd.	E* EPS Prospect	EPS	Not accessible	Foreign	China
Cherokee International	Darnell Group, 2005	EPS	http://www.cherokeepwr.com/	Multinational	United States
Chuangxing (Suzhou) Electronic Co., Ltd.		EPS	Not accessible	Foreign	China

Company Name	Source	BC/EPS	Website	US/Foreign/ Multinational	Country HQ
Cidco Communications, LLC	E* EPS Prospect	BC and EPS	http://www.cidcocom.com/	US	United States
Coldwatt (formerly GTI Power Systems)		EPS	http://www.coldwatt.com/	Multinational	United States
Commergy	PSMA Member	EPS	http://www.commergy.com/	Foreign	Ireland
Compact Power Systems (ESI)	PowerPulse article, 4/7/06, "Compact Power Partners with Mexicana Airlines"	BC	http://www.cellboost.com/us/index.htm	US	United States
Compact Power, Inc. (LG)	E* EPS Prospect	EPS	http://www.compactpower.com/	Multinational	South Korea
Conair	iStar Database	BC	http://www.conair.com/	Multinational	United States
CUI Inc	E* EPS Partner	EPS	http://www.cui.com/	US	United States
Custom Manufacturing & Engineering	E* EPS Prospect	EPS	http://www.custom-mfg-eng.com/	US	United States
Dalian Bingshan Group Co., Ltd. (DBGC)		EPS	http://en.bingshan.com/about/index.jsp?catid=9	Foreign	China
Dee Van Enterprise Co., Ltd.	E* EPS Prospect	BC and EPS	http://www.dveusa.com/	Multinational	United States
Delta Electronics Inc.	E* EPS Partner	EPS	http://www.deltaww.com/	Multinational	Taiwan
Densei- Lambda	Conversation with Subject Matter Expert	EPS	http://www.lambdapower.com/index.htm	Multinational	United States
DeWALT Industrial Tool Co.	E* EPS Prospect	BC and EPS	http://www.dewalt.com/us/core/	Multinational	United States
Digital Power Corporation	PowerPulse article, 6/13/05, "Gresham Power Intros Telkoor LSE Range Power Adapters"	EPS	http://www.digipwr.com/	Multinational	United States
Dongyang E&P	Darnell Group, 2005	BC and EPS	Not accessible	Foreign	South Korea
Eagle Picher Technologies	E* EPS Prospect	BC and EPS	http://www.eaglepicher.com/EaglePicherInternet/	US	United States
Eaglerise Electric and Electronic Co.	Globalsources.com	BC and EPS	http://www.2sunrise.com/english/company/profile.htm	Foreign	China
Earthwalk Communications	Hoover's Online Profile	BC	http://www.earthwalk.com	US	United States
Eaton Corporation, PowerWare Division (formerly Invensys Energy Systems)		BC and EPS	http://www.eaton.com/	Multinational	United States
ECU Electronics Industrial Co. Ltd.	Electronics and Electrical Web Directory (http://www.elecdir.com)	EPS	http://www.ecu.com.cn	Foreign	China

Company Name	Source	BC/EPS	Website	US/Foreign/ Multinational	Country HQ
EDAC Power	Powersupplies.net	EPS	http://www.edacpower.com/	Multinational	Taiwan
Efore USA	PSMA Member	EPS	http://usa.efore.com/	Multinational	Finland
Egston Eggenburger System Electronik		EPS	http://www.egston.com/index.asp	Multinational	Austria
Eldec (Crane)	Hoover's Online Profile	BC and EPS	http://www.eldec.com/	Multinational	United States
ElectriTek-AVT	E* EPS Prospect	EPS	http://www.electritek.com/	US	United States
Elgar Electronic	Hoover's Online Profile	EPS	http://www.elgar.com/	US	United States
Elonex	E* EPS Prospect	EPS	http://www.elonex.co.uk/	Foreign	United Kingdom
Elpac Power Supplies	DigiKey (http://www.digikey.com/) vendor list	BC and EPS		Multinational	United States
Eltek (bought Convertronic GMBH)	Power Sources Unlimited (http://www.psui.com/) supplier list	EPS	http://www.eltekenergy.com/	Multinational	Norway
Emerson (Astec, Artesyn)	E* EPS Prospect	BC and EPS	http://www.gotoemerson.com/jsp/index.jsp	Multinational	United States
EMS Wireless Healthcare	E* EPS Prospect	EPS	http://www.ems-t.com/	Multinational	United States
Enersafe, Inc. (Myers Power Products)		EPS	http://www.enersafeinc.com/	US	United States
Epilady	iStar Database	BC	http://www.epilady.com/	Multinational	Israel
Erskine Systems	Powersupplies.net	EPS	http://www.erskine-systems.co.uk/index.htm	Foreign	United Kingdom
ETA Electric Industries	Powersupplies.net	EPS	http://www.eta.co.jp/	Multinational	Japan
Etek Electronics	Globalsources.com	BC and EPS	http://www.e-tek.com.cn/EnglishIn/index.asp	Foreign	China
F.U.G. Elektronik	Powersupplies.net	EPS	http://www.fug-elektronik.de/webdir/1/english.htm	Foreign	Germany
Fairchild Semiconductor	E* EPS Prospect	EPS	http://www.fairchildsemi.com/	Multinational	United States
Fieldworks, Inc.	E* EPS Prospect	EPS	http://www.field-works.com/	Multinational	Germany
Flextronics	E* EPS Prospect	EPS	http://www.flextronics.com/	Multinational	Singapore
Fonebitz	Hoover's Online Profile	BC and EPS	http://www.fonebitz.co.uk/	Foreign	United Kingdom
Fortron/Source Corp.	E* EPS Prospect	EPS	http://www.fsusa.com/	Multinational	United States
Fountain Technologies, Inc.	E* EPS Prospect	EPS	Not accessible	US	United States

Company Name	Source	BC/EPS	Website	US/Foreign/ Multinational	Country HQ
FRIWO (Include Friwo Mobile Power and Friwo Power Solutions) (CEAG)		BC and EPS	http://www.friwo.de/	US	United States
FSP Group USA	Darnell Group, 2005	BC and EPS	http://www.fspgroupusa.com/	Multinational	Germany
Fuhua Electronic Co.	Globalsources.com	BC and EPS	http://www.fuhua-cn.com/EN/	Foreign	China
Fuji Electric Holdings Co., Ltd.	E* EPS Prospect	EPS	http://www.fujielectric.co.jp/eng/	Multinational	Japan
Fushan Chadi (International) Corporation		EPS	Not accessible	Foreign	China
GlobTek Inc	E* EPS Partner	BC and EPS	http://www.globtek.com/	Multinational	United States
Golden Eagle (Tianjin) Electronics Co., Ltd.		EPS	http://www.geec-tj.com/e-main.html	Foreign	China
Golden Edge	Globalsources.com	BC and EPS	http://www.goldenedge.com.hk/	Foreign	China
Grelco	Powersupplies.net	EPS	http://www.grelco.com/	Foreign	Spain
Group West Intl.	E* EPS Partner	EPS	Not accessible	Foreign	Taiwan
Guangdong Zhicheng-Champion Group		EPS	http://www.zhichengchampion.com/	Foreign	China
Guangzhou Ukicra Electric Co. Ltd.	Globalsources.com	EPS	http://www.ukicra.com	Foreign	China
Hangzhou Acepower Electronic Co., Ltd.		EPS	http://www.acepower.com.cn/index1.html	Foreign	China
Hangzhou Lianlong Electronic Co. Ltd.	Globalsources.com	EPS	http://www.lianlong.com.cn/	Foreign	China
Hangzhou Reliability Electronics Group (HRE)		EPS	http://english.51jishu.com/genesis/cgi/template/facade,company,DetailFront.vm?id=279	Foreign	China
Harding Energy	E* EPS Prospect	BC	http://www.hardingenergy.com/	US	United States
HCL Peripherals	E* EPS Prospect	EPS	http://www.hclperipherals.com	Foreign	India
HDM Systems	E* EPS Prospect	BC and EPS	http://www.fishingworld.com/HDMsystems/Default.tmpl?Cart=11425372243055719	US	United States
Helms-Man Ind. Co. Ltd.	Globalsources.com	BC and EPS	www.helms-man.com	Foreign	China
HindlePower	E* EPS Prospect	EPS	http://www.hindlepowerinc.com/	US	United States
Hipro Electronics	E* EPS Partner	EPS	http://www.hipro.com.tw/	Multinational	Taiwan
Hitachi, Ltd.	E* EPS Prospect	BC and EPS	http://www.hitachi.com	Multinational	Japan

Company Name	Source	BC/EPS	Website	US/Foreign/ Multinational	Country HQ
Hitek Power	PowerPulse article, 2/14/06, "HiTek Power Introduces Versatile Power Supply Family"	EPS	http://www.hitekpower.com/index.htm	Multinational	United Kingdom
Hitron Electronics	E* EPS Partner	EPS	http://www.hitron-e.com/index-2.htm	Foreign	Taiwan
http://www.huntkey.com/	PSMA Member	BC and EPS	http://www.huntkey.com/eng/index.asp	Multinational	China
Hualitong Electrics Co. Ltd.	Darnell Group, 2005	BC and EPS	http://www.hualitong.com/index.asp	Foreign	China
IBM Products United States	E* EPS Prospect	BC and EPS	http://www.ibm.com/us/	Multinational	United States
Industrial Scientific Corporation	Hoover's Online Profile	BC	http://www.indsci.com	Multinational	United States
Infineon Technologies Asia Pacific Pte Ltd		EPS	http://www.infineon.com	Multinational	Germany
Insight MEMEC	E* EPS Prospect	EPS	http://www.insight.memec.com	Foreign	China
Integrated Power Designs	Power Sources Unlimited (http://www.psui.com/) supplier list	EPS	http://www.ipdpower.com/home/	US	United States
International Components Corporation		EPS	http://www.iccus.com	Multinational	United States
International Rectifier	E* EPS Prospect	EPS	http://www.irf.com/indexsw.html	Multinational	United States
Intersil Corporation	E* EPS Prospect	EPS	http://www.intersil.com/cda/home/	Multinational	United States
IPCore Technologies (Shanghai) Co. Ltd.		EPS	http://www.ipcoreinc.com	Multinational	China
iTech	E* EPS Prospect	BC and EPS	http://www.itecheng.com/	US	United States
iWatt	E* EPS Prospect	BC and EPS	http://www.iwatt.com/	Multinational	United States
Jasper Electronics	Power Sources Unlimited (http://www.psui.com/) supplier list	EPS	http://www.jasperelectronics.com/	US	United States
Jentec Technology Co., LTD.	E* EPS Partner	EPS	http://www.jentec.com.tw	Multinational	Taiwan
Jerome Industries	E* EPS Partner	EPS	http://www.jeromeindustries.com/	US	United States
Jilin Great Wall Technical Electronic Co., Ltd.		EPS	http://www.jlgw.com	Foreign	China
Jinan Rongda Electronic Co., Ltd.	E* EPS Prospect	EPS	http://www.rdsps.com/	Foreign	China
Jinding Group	Globalsources.com	BC	http://www.jinding.com/	Foreign	China
J-N-J Miller Design Services, PLC	E* EPS Prospect	EPS	Not accessible	US	United States

Company Name	Source	BC/EPS	Website	US/Foreign/ Multinational	Country HQ
Joden Electron Co., Ltd.	E* EPS Prospect	EPS	http://www.jodenr.com.tw/	Multinational	Taiwan
Kaga Electronics (USA) (Volgen)	Darnell Group, 2005	EPS	http://www.volgen.com/	Multinational	Japan
Kepco	PowerPulse article, 2/8/06, "Kepco Power Offers RoHS and PFC"	EPS	http://www.kepcopower.com/index.htm	US	United States
Korea Data Systems Co. Ltd.	E* EPS Prospect	EPS	Not accessible	Foreign	South Korea
Kuantech(shenzhen) Co., Ltd	Globalsources.com	BC and EPS	http://www.twktec.com/en/default.htm	Foreign	China
Lead Year Enterprise	Darnell Group, 2005	BC and EPS	http://www.tigerpower.com.tw/	Multinational	Taiwan
Leader Electronics, Inc.	E* EPS Partner	EPS	http://www.lei.com.tw/	Multinational	Taiwan
LEM	E* EPS Prospect	EPS	http://www.lem.com/	Multinational	Switzerland
LG Electronics, Inc.	E* EPS Prospect	EPS	http://us.lge.com	Multinational	South Korea
Li Shin International Enterprise Corporation (LSE)	E* EPS Partner	EPS	http://www.lse.com.tw/	Multinational	Taiwan
Liaoning Zhongxin Autocontrol Co., Ltd.		EPS	Not accessible	Foreign	China
Lind Electronics, Inc.	E* EPS Prospect	EPS	http://www.lindelectronics.com/	US	United States
Linear Technology Corporation	PowerPulse article, 5/5/06, "Li-Ion Charger from Linear Delivers up to 2A in 16mm² Package"	BC	http://www.linear.com/index.jsp	Multinational	United States
Linvatec	E* EPS Prospect	EPS	http://www.conmed.com/	Multinational	United States
Lite-On Technology Corporation	E* EPS Partner	EPS	http://www.liteon.com/liteon/index.jsp	Multinational	Taiwan
Luoyang Rosen Technical Electronic Co., Ltd.		EPS	Not accessible	Foreign	China
Maccor, Inc.	E* EPS Prospect	EPS	http://www.maccor.com/	US	United States
Madsonline	E* EPS Prospect	EPS	http://www.madsonline.com	US	United States
Magna-Power Electronics	PSMA Member	EPS	http://www.magna-power.com/	US	United States
Magnetek Power Electronics Group (Acquired by Power One)		EPS	http://www.magnetekpower.com	Multinational	China
Maha Energy	Thomas Distributing (www.thomasdistributing.com) supplier listing	BC	http://www.mahaenergy.com/store/Index.asp	Multinational	United States

Company Name	Source	BC/EPS	Website	US/Foreign/ Multinational	Country HQ
Martek Power	Powersupplies.net	EPS	http://www.martekpower.com/	Multinational	France
Maxim Integrated Products	Conversation with Subject Matter Expert	BC	http://www.maxim-ic.com/	Multinational	United States
Mean Well Enterprise Co., Ltd.	PowerPulse article, 3/28/06, "Mean Well Expands AC-DC Line"	BC and EPS	http://www.meanwell.com/index.html	Multinational	Taiwan
MEI AH ELECTRICAL & INDUSTRY (HK) LTD.		EPS	http://www.mae.com.hk	Foreign	China
MGV Stromversorgungen	Powersupplies.net	EPS	http://www.mgv.de/page.php	Foreign	Germany
Micro Power Electronics	E* EPS Prospect	BC	http://www.micro-power.com/	US	United States
Microchip Technology, Inc.	Appliance Magazine Supplier Directory	BC	http://www.microchip.com/ParamChartSearch/chart.aspx?branchID=9011&mid=&lang=en&pageId=78 (battery charger page)	Multinational	United States
Midtronics	E* EPS Prospect	EPS	http://www.midtronics.com/	Multinational	United States
Milwaukee Electric Tool Corporation	iStar Database	BC	http://www.milwaukeetool.com/us/en/site.nsf/frmIndex?ReadForm	Multinational	China
MiTAC International Corporation	E* EPS Prospect	EPS	http://www.mitac.com/micweb/default.htm	Multinational	Taiwan
Mitsumi Electronics Corporation	E* EPS Prospect	EPS	http://www.mitsumi.com/	Multinational	Japan
Mobilecore, Inc.	E* EPS Prospect	EPS	Not accessible	US	United States
Mobility Electronics	Hoover's Online Profile	BC and EPS	http://www.mobl.com/	Multinational	United States
Motive Power USA (Enersys)	PowerPulse article, 2/10/06, "EnerSys and AccelRate Pen European License"	BC	http://www.enersysmp.com/	Multinational	United States
Multi Fineline Electronics (Multi-Flex). Chargers are a partner project with Mobility Electronics.	Hoover's Online Profile	BC	http://www.mflex.com/	US	United States
Murata Mfg. Co.	E* EPS Prospect	EPS	http://www.murata.com/	Multinational	Japan
N2Power, Inc (Qualstar)	Powersupplies.net	EPS	http://www.n2power.com/	US	United States
Nagano Japan Radio	E* EPS Prospect	EPS	http://www.njrc.jp/njrc-e/index.html	Foreign	Japan
National Semiconductor	SME	BC and EPS	http://www.national.com/	Multinational	United States

Company Name	Source	BC/EPS	Website	US/Foreign/ Multinational	Country HQ
Nexergy, Inc.	E* EPS Prospect	BC	http://www.nexergy.com/	US	United States
NF Corporation	E* EPS Prospect	EPS	http://www.nfcorp.co.jp/english/	Multinational	Japan
O2 Micro	Worldscope Company Profile	BC	http://www.o2micro.com/	Multinational	Cayman Islands
On Semiconductor	E* EPS Prospect	BC and EPS	http://www.onsemi.com/PowerSolutions/home.do	Multinational	United States
OPS Test Organization	E* EPS Partner	EPS	Not accessible	US	United States
OTE International	E* EPS Prospect	EPS	http://www.oteinternational.com/	Foreign	Taiwan
Panasonic	Darnell Group, 2005	BC and EPS	http://www.panasonic.com/flash.html	Multinational	Japan
PanPower AB	E* EPS Prospect	EPS	Not accessible	Foreign	Germany
Pantene Industrial	Darnell Group, 2005	BC and EPS	http://www.pantene.com.hk/main.html	Multinational	China
PEGA HK	Globalsources.com	EPS	http://www.pega-cn.com/index.php	Foreign	China
Permlight, Inc.	E* EPS Prospect	EPS	http://www.permlight.com/	US	United States
Peter Parts Electronics	E* EPS Prospect	EPS	http://www.peterparts.com/	Multinational	United States
Phihong USA Corporation	E* EPS Partner	BC and EPS	http://www.phihong.com	Multinational	Taiwan
Philips Consumer Electronics (Philips Semiconductor)		BC and EPS	http://www.semiconductors.philips.com/power	Multinational	Netherlands
Pioneer Magnetics	PSMA Member	EPS	http://www.pioneermag.com/	US	United States
Potrans	E* EPS Prospect	EPS	http://www.potrans.com/	Multinational	Taiwan
Power Density, Inc.	E* EPS Prospect	EPS	Not accessible	US	United States
Power Integrations, Inc.	E* EPS Prospect	BC and EPS	http://www.powerint.com	Multinational	United States
Power One	PowerPulse article, 4/11/06, "Power-One Added to Lucent Network Power Solution"	BC and EPS	http://www.power-one.com/	Multinational	United States
Powerbox Inc.	E* EPS Prospect	EPS	http://www.powerbox.se	Multinational	Sweden
PowerDesigners LLC	E* EPS Prospect	EPS	http://www.powerdesigners.com/	US	United States
PowerStream Technologies	E* EPS Prospect	EPS	http://www.powerstream.com/	US	United States
Pro Arch Technology Inc.	E* EPS Prospect	EPS	Not accessible	Foreign	China
PulseTech	E* EPS Prospect	EPS	http://www.pulsetech.com/	US	United States
RE Energy	E* EPS Prospect	EPS	Not accessible	US	United States

Company Name	Source	BC/EPS	Website	US/Foreign/ Multinational	Country HQ
Recoton Corp.	Thomas.net	BC	http://www.recoton.com/	US	United States
Roal Electronics	PSMA Member	BC and EPS	http://www.roalelectronics.com/	Multinational	Italy
Robert Bosch Tool Corporation	iStar Database	BC	http://www.boschtools.com/	Multinational	Germany
Ryobi	iStar Database	BC	http://www.ryobitools.com/	Multinational	China
Saft	E* EPS Prospect	EPS	http://www.saftbatteries.com/000-corporate/include-content/index_gb.html	Multinational	France
Sako Group Enterprise (includes ZHEJIANG SANKE ELECTRICAL, SHENZHEN GOLDEN SANKE ELECTRIC , HANGZHOU SANKE ELECTRICAL CO, SHANGHAISAKO ELECTRICALCO)		EPS	http://www.sanke.com/english/index.asp	Foreign	China
Salcomp (ShenZhen) Co. Ltd.	E* EPS Partner	EPS	http://www.salcomp.com	Multinational	China
Salton, Inc	iStar Database	BC	http://www.saltoninc.com/	US	United States
Sampo Technology Corporation	E* EPS Prospect	EPS	Not accessible	Multinational	China
Samsung Electronics Co., Ltd.	E* EPS Partner	EPS	http://www.samsung.com	Multinational	South Korea
Sanger HK International Corporation Ltd.		BC and EPS	Not accessible	Foreign	China
Sanken	E* EPS Prospect	EPS	http://www.sanken-ele.co.jp/en/index.html	Foreign	Japan
Schaefer	Globalspec.com	BC and EPS	http://www.schaeferpower.com/	Multinational	Germany
Schumacher Electric Corporation	E* EPS Prospect	BC and EPS	http://www.batterychargers.com/	US	United States
Seasonic	E* EPS Prospect	EPS	http://www.seasonic.com/co/index.jsp	Multinational	Taiwan
Segway	E* EPS Prospect	BC	http://www.segway.com/	US	United States
Selfcharge	E* EPS Prospect	EPS	http://www.selfcharge.com/	US	United States
Semikron	PowerPulse article, 4/12/06, "STMicroelectronics and Semikron form High-Power Team."	BC and EPS	http://www.semikron.com/internet/index.jsp?sekId=15	Multinational	Germany
Setec	Darnell Group, 2005	EPS	http://www.setec.com.au/pages/home_page.html	Foreign	Australia
Shanghai Guangtai Electronic Co., Ltd.		EPS	Not accessible	Foreign	China

Company Name	Source	BC/EPS	Website	US/Foreign/ Multinational	Country HQ
Shanghai Nanco Electronic Co., Ltd.	E* EPS Prospect	EPS	Not accessible	Foreign	China
Shanghai Sanki Electronic Industries Co., Ltd.		EPS	http://www.sanki-e.com/English/index.asp	Foreign	China
Shanghai Wenlida Electronical Co., Ltd.		EPS	Not accessible	Foreign	China
Shanghai Wenshan Electronic Co., Ltd.		EPS	Not accessible	Foreign	China
Shanghai Winsun Technologies Co., Ltd.		EPS	http://cw41008.chinaw3.com/en/index.asp	Foreign	China
Shanghai Xinfeng Electronic Co., Ltd.		EPS	http://www.sh-xinfeng.com	Foreign	China
Shenzhen	E* EPS Prospect	EPS	Not accessible	Foreign	China
Shenzhen Belta Electronics	Globalsources.com	BC and EPS	http://www.belta.cn	Foreign	China
Shenzhen Everbest Machinery Industry Co. Ltd		EPS	http://www.cem-meter.com.cn	Foreign	China
Shenzhen Huawei Technologies Co. Ltd.		EPS	http://www.huawei.com/	Multinational	China
Shenzhen Jewel Technology Group Co., Ltd.		EPS	http://www.szjewel.net	Foreign	China
Shenzhen Kuahong Technology Co., Ltd.		EPS	Not accessible	Foreign	China
Shenzhen Tenwei Electronics Co Ltd	Globalsources.com	BC and EPS	http://www.tenwei.com/	Foreign	China
Shenzhen Xixing Electronic Co. Ltd.	Globalsources.com	BC and EPS	http://www.xixingelec.com	Foreign	China
Shuttle Inc.	E* EPS Prospect	EPS	http://www.shuttle.com/	Multinational	Taiwan
Sino American Electronic Co.	Mentioned in 1/30/06 CEC Committee workshop on EPS	EPS	http://www.sac.com.tw/home.asp	Foreign	Taiwan
SIRTEC Intl. Co. Ltd.	E* EPS Partner	EPS	http://www.sirtec.com.tw/english/index.html	Foreign	Taiwan
SL Power Electronics Corp. (subsidiary of SL Industries)	PowerPulse article, 4/24/06, "SL Combines Ault and Condor into New Subsidiary"	BC and EPS	http://www.slindustries.com/sliwebsite/SLIWebSite4.nsf/f_Home	Multinational	United States
South Coast Technology	Powersupplies.net	EPS	http://www.scoasttech.com/index.html	US	United States
Speclin Enterprise Co.	Globalsources.com	EPS	http://www.speclin.com.tw/en/index/	Foreign	Taiwan
Splashpower Limited	iStar Database	BC	http://www.splashpower.com/	Multinational	United Kingdom

Company Name	Source	BC/EPS	Website	US/Foreign/ Multinational	Country HQ
ST Microelectronics	PowerPulse article, 4/12/06, "STMicroelectronics and Semikron form High-Power Team."	BC and EPS	http://www.st.com/stonline/	Multinational	Switzerland
Stak Enterprises	iStar Database	BC	http://www.washerwatcher.com/index.htm	US	United States
Stored Energy Systems	E* EPS Prospect	EPS	http://www.sens-usa.com/	US	United States
Summit Microelectronics Inc.	PowerPulse article, 2/21/06, "Digitally Programmable USB/AC Li-Ion Charger from Summit"	BC and EPS	http://www.summitmicro.com/home/	Multinational	United States
Sun Young Electronics	Globalsources.com	BC and EPS	http://www.sun-young.com	Foreign	China
Sunlight Power Supply	E* EPS Prospect	EPS	http://sungrow.cn/	Foreign	China
Sunpower Technology Corp.	Powersupplies.net	EPS	http://www.sunpower.com.tw/index_en.asp	Multinational	Taiwan
Sunstrong Enterprise	E* EPS Partner	EPS	http://www.sel.com.hk/	Foreign	China
Systel	E* EPS Prospect	EPS	http://www.systel.co.il	Foreign	Israel
Tabuchi Electric Co.	Darnell Group, 2005	BC and EPS	http://www.zbr.co.jp/top_e.htm	Multinational	Japan
Tamura Corporation	E* EPS Prospect	EPS	http://www.tamuracorp.com/	Foreign	Japan
Tandex Technologies Inc.	E* EPS Prospect	EPS	http://www.tandexlabs.com/	US	United States
TDC Power Products Co., Ltd.	Globalsources.com	BC and EPS	http://www.tdcpower.com/	Foreign	Taiwan
TDK Corp.	PowerPulse article, 3/28/06, "TDK Corp and Densei-Lambda Launch Unified TDK-Lambda Brand."	EPS	http://www.tdk.co.jp/tetop01/index.htm	Multinational	Japan
Technical Witts, Inc.	E* EPS Prospect	EPS	Not accessible	US	United States
Technics Electronic Co., Ltd.	E* EPS Prospect	EPS	Not accessible	Foreign	China
Tech-Power International Co.	E* EPS Partner	EPS	http://www.power-chinese.com/windows/index.htm?id=794488	Foreign	China
Techtium	E* EPS Prospect	BC	http://www.techtium.com/	Foreign	Israel
Ten Pao Industrial Company	E* EPS Prospect	EPS	http://www.tenpao.com/index.php?lang=en	Foreign	China

Company Name	Source	BC/EPS	Website	US/Foreign/ Multinational	Country HQ
Texas Instruments	Fortune 500	BC and EPS	http://www.ti.com/	Multinational	United States
Thales Communications, Inc.	E* EPS Prospect	EPS	http://www.thalescomminc.com/	US	United States
Total Power International	E* EPS Partner	EPS	http://www.total-power.com	Multinational	United States
Traco Power	Power Sources Unlimited (http://www.psui.com/) supplier list	EPS	http://www.tracopower.com/	Multinational	Switzerland
Transoner	E* EPS Prospect	EPS	http://www.transoner.com/	US	United States
Transtector Systems, Inc.	E* EPS Prospect	EPS	http://www.transtector.com/	US	United States
Trimag	Power Sources Unlimited (http://www.psui.com/) supplier list	EPS	http://www.trimag.com/	Foreign	Canada
TT Systems LLC	E* EPS Prospect	EPS	Not accessible	US	United States
Tyco	E* EPS Prospect	EPS	http://www.tyco.com/	Multinational	United States
Ultravolt	Powersupplies.net	EPS	http://www.ultravolt.com/	US	United States
Uniross	PowerPulse article, 10/19/06, "Uniross Rechargeable Batteries Launches in North America"	BC	http://www.uniross.com/	Multinational	France
Vectrix Corp.	E* EPS Prospect	EPS	http://www.vectrixusa.com/news/inthenews.html	Multinational	Italy
Vicor	PowerPulse article, 4/25/06, "Vicor Reports 44% Gross Margins in First Quarter"	EPS	http://www.vicorpower.com/	Multinational	United States
V-Infinity	PowerPulse article, 6/8/06, "V-Infinity Introduces New Line of Compact Switchers"	EPS	http://www.v-infinity.com/	US	United States
Vmark International (Sunlogic Electrical Appliances)		BC and EPS	http://www.vmarkpower.com	Foreign	China
W.F. White International	E* EPS Prospect	EPS	Not accessible	US	United States
Wah Hing Transformer Mfy. Ltd.	Globalsources.com	BC and EPS	http://www.wahhing.com.hk/products.htm	Foreign	China
WAHL	iStar Database	BC and EPS		Multinational	United States

Company Name	Source	BC/EPS	Website	US/Foreign/ Multinational	Country HQ
Wall Industries	PowerPulse article, 1/2/06, "Wall Industries Launches Wall-Mounted Power with Interchangeable Plugs"	EPS	http://www.wallindustries.com/index.asp	US	United States
Wilson Greatbatch	E* EPS Prospect	EPS	http://www.greatbatch.com/	US	United States
Wireless Xcessories	Hoover's Online Profile	BC	http://www.wirexgroup.com/	US	United States
Xantrex Technology	Globalspec.com	BC	http://www.xantrex.com/index.asp	Multinational	Canada
XP Power	PowerPulse article, 6/6/06, "XP Power Introduces 212W AC/DC Switcher in Small Package"	EPS	http://www.xppowerplc.com/index.html	Multinational	United Kingdom
Yangzhou East Corp.	E* EPS Prospect	EPS	http://www.yz-east.cn	Foreign	China
Yinli Electronics (H.K.) Co., Ltd.	E* EPS Prospect	EPS	Not accessible	Foreign	China
Yokogawa	E* EPS Prospect	EPS	http://www.yokogawa.com/	Multinational	Japan
ZAP Portable Energy	PowerPulse article, 5/15/06, "ZAP Introduces Lithium Battery Line for the iPod"	BC	http://www.zapworld.com/index.asp	US	United States
Zhejaing Changkai Electric Co.	E* EPS Prospect	EPS	http://www.made-in-china.com/showroom/changkaicn	Foreign	China
Zhongshan Huayu	Globalsources.com	BC	http://www.huayu-zs.com/profile.asp	Foreign	China
Zhongshan Huiyang Electric Appliance		EPS	http://www.hui-yang.com/en/aboutus.htm	Foreign	China
Zhongshan Kmate Electronics	Globalsources.com	BC and EPS	http://www.k-mate.com/index.asp	Foreign	China
Zinc Matrix Power	E* EPS Prospect	EPS	http://www.zmp.com/	US	United States
ZTE Corporation	E* EPS Prospect	EPS	http://www.zte.com.cn/English/index.jsp	Multinational	China